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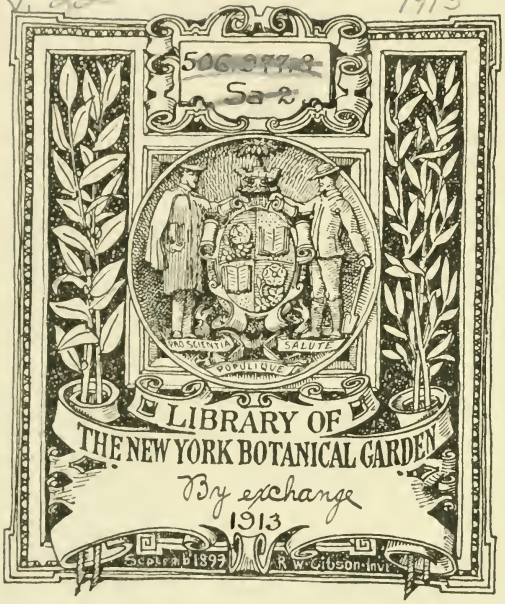

TRANSACTIONS

OF

THE ACADEMY OF SCIENCE OF ST. LOUIS.

VOL. XXII.

JANUARY, 1913, TO DECEMBER, 1913.

PUBLISHED UNDER DIRECTION OF THE COUNCIL.

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LIST OF OFFICERS, 1913.

President	Edmund A. Engler.
First Vice President	Francis E. Nipher.
Second Vice President	Arthur E. Ewing.
Recording Secretary	J. A. Drushel.
Corresponding Secretary	George O. James.
Treasurer	H. E. Wiedemann.
Librarian	Wm. L. R. Gifford.
Curators	Julius Hurter. Philip Rau. Hermann von Schrenk.
Directors	Adolf Alt. H. M. Whelpley.

MEMBERS.

1. Patrons.

Bixby, William Keeney.....Kingshighway and Lindell Bls.
Eliot, Henry Ware.....4446 Westminster Pl.
†Harrison, Edwin.....
Mallinckrodt, Edward.....26 Vandeventer Pl.
McMillan, Mrs. Eliza.....25 Portland Pl.
McMillan, William Northrop...Century Bldg.

2. Honorary Members.

Arrhenius, Prof. Svante.....University of Stockholm, Sweden.
Bahlsen, Prof. Dr. Leopold....University of Berlin, Germany.
Kitasato, Prof. Shibasaburo....University of Tokyo, Japan.
Lewald, Geh. Oberreg. Rath Theodor.....Berlin, Germany.
Limburg, Stirum, Graf.....Berlin, Germany.
Orth, Geh. Rath Dr. Johann...University of Berlin, Germany.
Ostwald, Prof. Wilhelm.....University of Leipzig, Germany.
Ramsay, Sir William.....Royal Institute, London, England.
Rutherford, Prof. Ernest.....University of Manchester, England.
Springer, Frank.....U. S. National Museum, Washington, D. C.
Trelease, William.....University of Illinois, Urbana, Ill.
Waldeyer, Geh. Rath Prof. Dr. Wilhelm.....University of Berlin, Germany.
Wassermann, Prof. Dr. A.....University of Berlin, Germany.
Wittmack, Geh. Reg. Rath Prof. Dr. L.....University of Berlin, Germany.

† Deceased.

3. Active Members.

Alleman, Gellert[1] ..... Swarthmore College, Swarthmore, Pa.
Allen, George L. ..... 26 Westmoreland Pl.
Alt, Adolf ..... 316 Metropolitan Bldg.
Altheimer, Benjamin ..... Melrose Apartments.
Ameiss, F. C. ..... 4908d Euclid Terrace.

Baker, Robert H.[1] ..... University of Missouri, Columbia, Mo.
Barck, Carl ..... Humboldt Bldg.
Barnard, George D. ..... Vandeventer and Laclede Aves.
Baumgarten, Walter ..... Humboldt Bldg.
Beckwith, Thomas[1] ..... Charleston, Mo.
Beede, J. W.[1] ..... Wall and Atwater Sts., Bloomington, Ind.
Bemis, S. A. ..... Fourth and Poplar Sts.
Bessey, Charles Edwin[1] ..... University of Nebraska, Lincoln, Neb.
Blair, V. P. ..... Metropolitan Bldg.
Blankinship, Joseph William[1] .. 2525 Hilgard Ave., Berkeley, Cal.
Blewett, Ben ..... Ninth and Locust Sts.
Bock, George W. ..... 2904 Allen Ave.
Borgmeyer, Charles J. ..... St. Louis University.
Bostwick, Arthur E. ..... 70 Vandeventer Pl.
Brandenburger, W. A.[1] ..... 312 Inverness Bldg., Sacramento, Cal.
Branner, J. C.[1] ..... Stanford University, Cal.
Brennan, Martin S. ..... 6304 Minnesota Ave.
Brimmer, George G. ..... 6900 Michigan Ave.
Britton, F. H.[1] ..... Kirkwood, Mo.
Brock, James E. ..... Mississippi Valley Trust Co.
Brookings, Robert S. ..... 6510 Ellenwood Ave.
Brown, Daniel S.[1] ..... Brownhurst, Kirkwood, Mo.
Buehler, H. A.[1] ..... Rolla, Mo.
Burg, William ..... 4439 Washington Boul.
Busch, Aug. A. ..... Busch Pl.
Bush, Benjamin Franklin[1] ..... Courtney, Mo.
Butler, William M. ..... Yeatman High School.

[1] Non-resident.

Cale, George W., Jr.....12 Lennox Pl.
Campbell, James A.....Mermod Jaccard Bldg.
Carleton, Murray.....1135 Washington Ave.
Carpenter, George O.....12 Portland Pl.
Carr, Peyton T.....62 Vandeventer Pl.
Carver, George Washington[1]...Tuskegee, Ala.
Caspari, Charles E.....4060 Westminster Pl.
Catlin, Daniel.....Security Bldg.
Chambers, C. O.[1].....University of Cincinnati, Cincinnati, O.
Chappell, W. G.....501 Clara Ave.
Chenery, Winthrop Holt.....Washington University.
Clarke, Enos[1].....Kirkwood, Mo.
Clopton, Malvern B.....Humboldt Bldg.
Colnon, R. S.....506 Merchants' Laclede Bldg.
Conzelman, Theophilus.....5260 Washington Boul.
Cook, Abraham.....4208 Pine St.
Cook, Francis E.....5510 Cates Ave.
Cook, Isaac T.....Chemical Bldg.
Cook, Jerome E.....4254 Lindell Boul.
Cramer, Gustav.....Care Cramer Dry Plate Co.
Crawford, Hanford.....4442 Lindell Boul.
Crecelius, Elyse C.....1110 Dillon St.
Curley, Francis E. A.....6143 Berlin Ave.
Curtis, William S.....Washington University.

Dameron, Edward Caswell[1]....Clarksville, Mo.
Danforth, Charles H.....Washington University, Medical Department.
Davis, H. N.....56 Vandeventer Pl.
Davis, John D.....Third National Bank Bldg.
Dewey, Lyster H.[1].....4612 Ninth St., N. W., Washington, D. C.
Diehm, Ferdinand.....6175 Kingsbury Boul.
Doan, George P.....42 Portland Pl.
Dock, George.....Washington University, Medical Department.
Dorsett, Walter B.....Wall Bldg.
Dougan, Lewis M.....3955 Botanical Ave.
Drosten, F. W.....3521 Victor St.
Drushel, J. A.....Teachers' College.

Duggar, Benjamin M.....Missouri Botanical Garden.
Duncker, Charles H.....3636 Page Ave.

Ebeling, A. W.[1].....Warrenton, Mo.
Eberle, E. G.[1].....416 Jackson St., Dallas, Texas.
Eilers, Roy M.....Central National Bank Bldg.
Eimbeck, August F.[1].....New Haven, Mo.
Eliot, Edward C.....5468 Maple Ave.
Emerson, John B.....Syndicate Trust Bldg.
Emmel, Victor E.....Washington University, Medical Department.
Engler, Edmund Arthur.....Washington University.
Ericson, Eric John.....1420 Clara Ave.
Erker, Adolph P.....608 Olive St.
Espenschied, Charles .....3500 Washington Ave.
Evers, Edward .....1861 North Market St.
Ewers, A. F.....3411 Pestalozzi St.
Ewing, Arthur E.....5956 Cabanne Pl.

Fawcett, H. S.[1].....Whittier, Cal.
Fischel, Walter .....5284 Westminster Pl.
Fischel, Washington E.....Humboldt Bldg.
Fish, E. R.....2449 E. Marcus Ave.
Floyd, B. F.[1].....Gainesville, Fla.
Fordyce, John R.[1].....2223 Louisiana St., Little Rock, Ark.
Fordyce, S. W.....21 Washington Terrace.
French, George Hazen[1].....Carbondale, Ill.
Frerichs, Frederick W.....4320 Washington Boul.
Frick, John Henry[1].....Warrenton, Mo.
Fry, Frank R.....4609 McPherson Ave.
Funkhouser, Robert Monroe...4354 Olive St.

Garman, Harrison[1] .....Lexington, Ky.
Gecks, Frank .....3453 Magnolia Ave.
Geitz, H. A.[1].....17 West End Ave., Rockaway Park, Long Island, N. Y.
Gifford, William L. R.....Mercantile Library.
Gill, Charles M.....Teachers' College.
Gillette, C. P.[1].....Fort Collins, Colo.
Glasgow, Frank A.....3894 Washington Ave.

Goldstein, Max A.....3858 Westminster Pl.
Goltra, Edward F.....4416 Lindell Boul.
Goodman, Charles H.....Wall Bldg.
Gratz, Benjamin.....Rialto Bldg.
Graves, William W.....Metropolitan Bldg.
Greene, F. C., Jr.[1].....Rolla, Mo.
Greenman, Jesse M.....Missouri Botanical Garden.
Grindon, Joseph.....3894 Washington Ave.
Gundelach, William J.....4458 Washington Boul.
Gundlach, John H.....3615 North Broadway.
Guy, William E.....10 Portland Pl.

Haarstick, Henry C.....St. Louis Union Trust Bldg.
Hall, Robert A.[1].....323 Sixth Ave., S. E.,
Minneapolis, Minn.
Hambach, Gustav[2].....2605 Louisiana Ave.
Hard, M. E.[1].....Kirkwood, Mo.
Harder, Ulrich.....8015 Florissant Ave.
Hartmann, Rudolph.....3859 Flora Boul.
Hecker, Frederick[1].....Argyle Bldg.,
Kansas City, Mo.
Held, George A.....International Bank.
Hendrich, Walter F.....6228 Washington Boul.
Herf, Oscar.....Pierce Bldg.
Hoffman, Philip.....3657 Delmar Ave.
Hoke, William E.....304 North Third St.
Holman, C. L.....Laclede Gas Bldg.
Hughes, Charles Hamilton.....Metropolitan Bldg.
Hughes, Marc Ray.....Metropolitan Bldg.
Hume, H. Harold[1].....Glen St. Mary, Fla.
Hurter, Julius.....2346 South Tenth St.

Ilhardt, William K.....Euclid and Delmar Aves.
Irish, Henry C.....Commonwealth Trust Bldg.

James, George Oscar.....Washington University.
Johnson, Albert L.[1].....Mutual Life Insurance Bldg.,
Buffalo, N. Y.
Jonas, Ernest.....465 North Taylor Ave.

[2] Elected a life-member January 3, 1882.

Jones, Breckinridge.....45 Portland Pl.
Jones, Robert McKittrick.....6 Westmoreland Pl.

Kammerer, Alfred L.....Tower Grove and Flad Aves.
Kennett, Luther M.....3507 Lucas Ave.
Kessler, George E.....Security Bldg.
Kessler, J. J.....224 South Vandeventer Ave.
Keyes, Charles R.[1].....944 Fifth St., Des Moines, Ia.
King, Goodman.....78 Vandeventer Pl.
Kirchner, Walter C. G.....1127 North Grand Ave.
Klem, Mary J.....2853a Accomac St.
Knapp, H. P.....Eighteenth and Olive Sts.
Knight, H. F.....4433 Westminster Pl.
Knight, S. S.....6700 Manchester Ave.

La Brie, Joseph Damas[1].....504 Keith & Perry Bldg., Kansas City, Mo.
Lang, George, Jr.....3601 Salena St.
Langsdorf, Alexander S.....Washington University.
Larkin, E. H.....3600 North Broadway.
Lawver, Albert Briggs.....5715 Clemens Ave.
Leavitt, Sherman[1].....Illinois College, Jacksonville, Ill.
Lewis, E. G.[1].....University City, Mo.
Lichter, John J.....1740 Simpson Pl.
Loeb, Leo.....St. Louis Skin and Cancer Hospital.
Luedde, William H.....Metropolitan Bldg.
Lukens, C. DeWitt.....4908 Laclede Ave.

Mallinckrodt, Edward, Jr.....Mallinckrodt Chemical Works.
Mardorf, W. C.....2136 South Grand Ave.
Markham, George Dickson.....4961 Berlin Ave.
Mason, Silas C.[1].....R. F. D. No. 1, Bethesda, Md.
Matthews, Leonard.....5447 Cabanne Pl.
Mauran, John Lawrence.....1620 Chemical Bldg.
McBride, W. J.[1].....Haskell & Barker Car Co., Michigan City, Ind.
McCulloch, Richard.....3869 Park Av.
McLeod, N. W.....Lumberman's Bldg.
McMaster, LeRoy.....Washington University.
Meier, Theodore G.....5220 Washington Boul.
Mepham, G. S.....4434 Westminster Pl.

Mesker, Frank.....421 South Sixth St.
Mitchell, E. T.[1].....7730 Jeanette St., New Orleans, La.
Monell, Joseph T.....3454 Halliday Ave.
Monfort, W. F.....77 East May St.
Montague, John E.....National Bank of Commerce Bldg.
Moore, George T.....Missouri Botanical Garden.
Moore, Philip N.....Merchants' Laclede Bldg.
Moore, Robert.....61 Vandeventer Pl.
Mudd, Harvey G.....408 Humboldt Bldg.
Mueller, Ambrose[1].....Webster Groves, Mo.

Nagel, Charles.....Security Bldg.
Nasse, August.....2323 Lafayette Ave.
Nauer, Albert R.....4634 Nebraska Ave.
Nicolaus, Henry.....2149 South Grand Ave.
Nipher, Francis E.....Washington University.
Nisbet, Fritz.....New National Bank of Commerce Bldg.
Noel, Alexander H.....1323 Geyer Ave.
Nolker, William H.....Fifteenth and Pine Sts.
Norvell, Saunders.....LaSalle Bldg.

Ohlweiler, W. W.....4026a Shenandoah Ave.
Olshausen, Ernest P.....1115 Rutger St.
Opie, Eugene L.....Washington University, Medical Department.
O'Reilly, Andrew J.....1720 Pierce Bldg.
O'Reilly, Robert J.....27 Washington Terrace.

Padberg, Aloys J.....3900a Easton Ave.
Palmer, Ernest Jesse[1].....321 S. Allen St., Webb City, Mo.
Pammel, Louis Hermann[1].....Ames, Iowa.
Pantaleoni, Guido.....15 Lennox Pl.
Parker, George Ward.....501 Liggett Bldg.
Parker, L. S.[1].....Jefferson City, Mo.
Perkins, Albert T.....401 North Fourth St.
Pettus, Charles P.....33 Westmoreland Pl.
Pettus, W. H. H.....4373 Westminster Pl.
Pitzman, Julius.....6 Kingsbury Pl.

Post, Martin Hayward.....5371 Waterman Ave.
Priest, Henry Samuel.....New National Bank of Commerce Bldg.
Pyle, Lindley[1].....1619 Massachusetts Ave., Cambridge, Mass.

Randolph, Tom.....7 Kingsbury Pl.
Rassieur, Leo.....Fourth and Market Sts.
Rau, Philip.....4932 Botanical Ave.
Reber, H. Linton.....Kinloch Bldg.
Reber, Maxime.....La Salle Bldg.
Reed, George M.[1].....809 Virginia Ave., Columbia, Mo.
Robarts, Heber[1].....Belleville, Ill.
Roever, William Henry.....Washington University.
Rolfs, Peter H.[1].....Gainesville, Fla.
Rosenwald, Lucian[1].....412 Delaware St., Kansas City, Mo.
Rowse, E. C.....Chemical Bldg.
Ruf, Frank A.....5863 Cabanne Pl.
Rusch, Henri.....City Hall.

Sampson, Francis A.[1].....Columbia, Mo.
Sargent, Charles Sprague[1].....Jamaica Plains, Mass.
Sauer, William E.....Humboldt Bldg.
Scanlan, Philip C.....4450 Lindell Boul.
Schlueter, Robert E.....909 Park Ave.
Schlueter, W. H.[1].....Kirkwood, Mo.
Schramm, Jacob.....Missouri Botanical Garden.
Von Schrenk, Hermann.....Tower Grove and Flad Aves.
Schwarz, Ernest.....6310 Newstead Ave.
Schwarz, Frank.....1813 Lafayette Ave.
Schwarz, Henry.....440 North Newstead Ave.
Schwarz, Herman[1].....720 Clark Ave., Webster Groves, Mo.
Schweyer, George.....4252 Blaine Ave.
See, Thomas Jefferson Jackson[1].Naval Observatory, Mare Island, Cal.
Selby, Augustine Dawson[1].....Wooster, Ohio.
Senter, Charles Parsons.....1 Beverly Pl.
Shackleford, Ben G.....4511 McPherson Ave.

Shaffer, Philip A.....Washington University, Medical Department
Shahan, William E.....5234a Von Versen Ave.
Shannon, James I.....St. Louis University.
Shapleigh, Alfred Lee.....3636 Delmar Ave.
Shapleigh, John B.....Humboldt Bldg.
Sheldon, F. E.....Chemical Bldg.
Shepley, John F.....53 Portland Pl.
Shimek, B.[1].....Iowa City, Iowa.
Simmons, E. C.....Ninth and Spruce Sts.
Simmons, Wallace D.....Ninth and Spruce Sts.
Skinker, Thomas K.....Pierce Bldg.
Slater, Charles H.[1].....130 West Swan Ave., Webster Groves, Mo.
Sluder, Greenfield.....3542 Washington Ave.
Smith, D. S. H.....4388 Westminster Pl.
Smith, George M.....Washington University, Medical Department.
Smith, Jared G.[1].....Kealakekua, Hawaiian Islands.
Standley, Paul C.[1].....Division of Plants, National Museum, Washington, D. C.
Starr, John E.[1].....50 Church St., New York City.
Stelzleni, G. M.....1215 North Grand Ave.
Stennett, W. H.[1].....203 Linden Ave., Oak Park, Ill.
Stevens, Charles D.....5352 Vernon Ave.
Stevens, Wyandotte James.....4458 Olive St.
Stix, Charles A.....Stix, Baer & Fuller Dry Goods Company.
Stocker, George J.....2833 South Kingshighway Bl.
Sultan, Fred W.....112 North Second St.
Summa, Hugo.....Metropolitan Bldg.
Suppan, Leo.....2648 Russell Ave.

Taussig, Albert E.....Metropolitan Bldg.
Terry, Robert James.....Washington University, Medical Department.
Thacher, Arthur.....5185 Lindell Boul.
Thomas, John R.....4128 Washington Boul.
Thomasson, Hugh W.....703 North Grand Ave.
Thompson, Charles Henry.....Missouri Botanical Garden.
Timmerman, Arthur H.....6400 Plymouth Ave.
Todd, Charles A.....3723 Delmar Ave.

Tuholske, Herman.....465 North Taylor Ave.
Turner, Charles H.....Sumner High School.
Tuttle, Daniel S.....74 Vandeventer Pl.

Van Ornum, John Lane.....Washington University.
Vickroy, Wilhelm Rees.....2901 Rauschenbach Ave.

Walbridge, C. P.....Fourth and Market Sts.
Waldo, C. A.....Washington University.
Walsh, Julius S.....Fourth and Pine Sts.
Watts, Millard F.....5740 Cabanne Pl.
Weichsel, Hans.....6400 Plymouth Ave.
Werner, Louis.....Fullerton Bldg.
Wheeler, H. A.....3437 Lucas Ave.
Whelpley, Henry Milton.....2342 Albion Pl.
Whitaker, Edwards.....300 North Fourth St.
Whitelaw, Oscar L.....409 North Second St.
Whitten, John Charles[1].....Columbia, Mo.
Widmann, Otto.....5105 Von Versen Ave.
Wiedemann, H. E.....1105 Holland Bldg.
Wiener, Meyer.....3854 Westminster Pl.
Wiggins, Charles.....23 Portland Pl.
Wilson, M. E.....Washington University.
Winkelmeyer, Christopher.....4585 West Pine St.
Wislizenus, Frederick A.....Washington University.
Wolfner, Henry L.....4563 Forest Park Boul.
Woodward, Calvin Milton.....3013 Hawthorne Boul.
Woodward, Walter B.....Woodward & Tiernan Ptg. Co.
Wright, George M.....4457 Westminster Pl.
Wulfing, J. Max.....3448 Longfellow Boul.

Zahorsky, John.....1460 South Grand Ave.
Zellweger, John.....1900 Adelaide Ave.

CONSTITUTION.

ARTICLE I. NAME.

SECTION 1. This Association shall be called "The ACADEMY OF SCIENCE OF ST. LOUIS."

ARTICLE II. OBJECT.

SECTION 1. It shall have for its object the promotion of science.

SEC. 2. As means to this end the Academy shall hold meetings for the consideration and discussion of scientific subjects; shall take measures to procure original papers upon such subjects; and shall, as often as may be practicable, publish its transactions. It shall also establish and maintain a cabinet of objects illustrative of the several departments of science, and a library of works relating to the same. It shall also place itself in communication with other scientific institutions.

ARTICLE III. MEMBERS.

SECTION 1. The Academy shall consist of *Active Members, Corresponding Members, Honorary Members* and *Patrons.*

SEC. 2. *Active Members* shall be persons interested in science, and they alone shall conduct the affairs of the Academy.

SEC. 3. Persons not living in the City or County of St. Louis who may be disposed to further the object of the Academy by original researches, contributions of specimens, or otherwise, may be elected *Corresponding Members.*

SEC. 4. Persons not living in the City or County of St. Louis may be elected *Honorary Members* by virtue of their attainments in science.

Sec. 5. Any person conveying to the Academy the sum of one thousand dollars ($1,000) or its equivalent, may be elected a *Patron.*

Sec. 6. Persons may be admitted to any of the preceding classes of membership or dismissed therefrom in accordance with the regulations prescribed by the By-Laws.

ARTICLE IV. OFFICERS.

Section 1. The officers of the Academy shall be chosen from the active members, and they shall consist of a

President,
First Vice-President,
Second Vice-President,
Recording Secretary,
Corresponding Secretary,
Treasurer,
Librarian,
Three Curators,
Two Directors.

Said officers shall be elected at the time and in the manner prescribed by the By-Laws, and shall hold their offices for one year, or until their successors are elected.

Sec. 2. The duties of these officers shall be such as are customary and as prescribed by the By-Laws.

ARTICLE V. COUNCIL.

Section 1. The officers shall constitute the Council of the Academy and at its meetings five shall constitute a quorum.

Sec. 2. The duties of the Council shall be to consider all plans conducive to the welfare of the Academy; to audit all bills and order payment of such as they may approve; to consider all applications for membership; and to administer the business of the Academy, subject to the Constitution and By-Laws and to such instructions as may be given by the Academy.

ARTICLE VI. MEETINGS.

Section 1. The meetings of the Academy shall be held at such times and places as the By-Laws may direct.

ARTICLE VII. AMENDMENTS.

SECTION 1. Amendments to this Constitution shall be submitted in writing at a regular meeting. They shall be open to discussion until at least the second meeting thereafter. They may then be adopted by a two-thirds vote of a letter-ballot, conducted in the manner prescribed by the Council.

ARTICLE VIII. SECTIONS.

SECTION 1. To encourage and promote special investigations in any branch of science, members of the Academy may form Sections, which shall be constituted as herein provided.

SEC. 2. For the formation of a Section, written application shall be made to the Academy, at a regular meeting, by not less than six active members.

On the approval of this application by the affirmative vote of two-thirds of the members present at the next regular meeting, the Section shall be established and the names of the petitioners shall be recorded on its minutes as its founders.

SEC. 3. Sections may increase the number of their members by election, but only members of the Academy shall be elected members of any of the Sections.

SEC. 4. The officers of each Section shall be a Chairman and a Secretary, who shall be elected by its members at the first meeting of the Section, and subsequently at the first meeting in January of each year.

SEC. 5. The collections and books of each Section are the common property of the Academy. Donations of books and specimens made to or for any Section shall be received as donations to the Academy for the use of the Section.

SEC. 6. A report of the proceedings of each Section shall be submitted to the Academy at least once every month. Papers read before any Section with a view to publication by the Academy shall take the same course as papers read before the Academy.

SEC. 7. On all points not herein provided for, each Section shall be governed by the Constitution, By-Laws and instructions of the Academy.

BY-LAWS.

I. REGULAR MEETINGS.

The regular meetings of the Academy shall be held on the first and third Monday evenings of every month, unless otherwise ordered by the Council.

II. SPECIAL MEETINGS.

Special meetings may be called by the President at his discretion, and shall be called by him on the written request of three or more members.

III. NOTICE OF MEETINGS.

The Recording Secretary shall send a notice of each meeting to every active member at least two days before such meeting.

IV. QUORUM.

Seven members shall constitute a quorum, but four members shall constitute a legal meeting for reading of papers.

V. ORDER OF BUSINESS.

The order of proceeding, at the regular meetings of the Academy, shall be as follows:

1. Call to order by President.
2. Scientific Program.
   a. Papers as announced.
   b. Reports of Sections.
   c. Other communications (brief).
   d. Donations to the Museum and Library.
   e. Announcements by President (of special interest to visitors.)

3. Business Meeting.
   a. Minutes of last meeting.
   b. Report of the Council.
   c. Reports of Committees.
   d. Report of the Corresponding Secretary.
   e. Deferred Business.
   f. New Business.
   g. Elections.
   h. Proposals for Membership.
   i. Adjournment.

VI. CORRESPONDING SECRETARY.

It shall be the duty of the Corresponding Secretary to conduct the correspondence and report to the Academy.

VII. TREASURER.

The Treasurer shall collect all moneys due the Academy; be custodian of all its funds, and pay such bills against the Academy as the Council shall approve. The Treasurer shall deposit the moneys and invest the funds of the Academy in its name and by and with the advice of the Council. Besides his annual report to the Academy, the Treasurer shall make such further reports and statements concerning the financial affairs of the Academy as the Council may from time to time require. Before entering upon his duties, the Treasurer shall give bond in such sum as may be required by the Council.

VIII. LIBRARIAN.

The Librarian shall take charge of all books belonging to or deposited with the Academy, and shall be responsible for the same; he shall keep a catalogue thereof, in which the names of contributors shall be inscribed; he shall superintend the distribution of all the publications of the Academy.

IX. COUNCIL.

The Council shall act as a publication committee; shall prepare a program for each meeting, and make rules and regulations for their own guidance, not inconsistent with the Constitution and By-Laws.

X. ELECTION OF OFFICERS.

A nominating committee of three active members who are not officers of the Academy shall be elected at the first regular meeting in December. This committee shall nominate candidates for all the offices for the ensuing year, and report the nominations at the following meeting, when other nominations may be made by any active member. The Recording Secretary shall mail to every active member a list of the nominees for office, at least ten days preceding the annual meeting. The polls shall be closed at 6 p. m. on the day of the annual meeting, after which the nominating committee shall count the ballots and announce the results to the Academy. A plurality of the votes cast shall suffice to elect.

XI. VACANCIES.

All vacancies shall be filled by the Council in a regular or called meeting, notice whereof having been given at least two days previously.

XII. ELECTION OF MEMBERS.

A candidate for admission to the Academy shall be proposed by not less than two members at any regular meeting. The proposal must then be referred to the Council, and if upon examination they shall find the candidate to be eligible and worthy of membership, they shall order the question as to his admission to be submitted to the Academy for ballot. If there be five votes in the negative, the candidate shall be rejected, and shall not be again voted upon for twelve months after such rejection. But if the number of negative votes be less than five, the candidate shall be elected, but shall not be considered a member until he shall have paid the annual dues for the current year. Any failure to pay the annual dues within thirty days after the candidate has been notified of his election, shall work a forfeiture of all rights under said election, if the Council shall so determine. No entry shall be made on the record of the rejection of any candidate.

XIII. RESIGNATION OF MEMBERS.

Any member whose dues have been fully paid may withdraw from the Academy by a written resignation. Non-payment of dues for one year or longer may be treated as equivalent to resignation; but before any member is dropped from the rolls for delinquency, he shall be entitled to not less than four weeks' notice.

XIV. EXPULSION OF MEMBERS.

Upon the written request of five members, that, for cause stated, any member be expelled, the Council shall consider the matter, and if they deem it best, shall advise the member that his resignation will be accepted. He shall, however, have the right to demand and shall be given a copy of the charges against him, and shall have a reasonable time to present a written defense. The Council may then pass finally upon the matter, and if resignation has not been tendered, or a satisfactory defense made, may by an affirmative vote of four of their number expel the member, in which case they shall notify him and the Academy of their action, and his name shall be at once dropped from the list of members.

XV. INITIATION FEES AND DUES.

Annual dues shall be paid at the beginning of each year. Resident active members shall pay annual dues of six dollars, and non-resident active members shall pay annual dues of three dollars. There shall be no initiation fee.

XVI. HONORARY MEMBERS AND PATRONS.

Honorary members and Patrons shall be recommended by the Council, and elected by the unanimous vote of the members present at any regular meeting.

XVII. PUBLICATIONS.

Patrons, honorary members, and all active members not in arrears shall be entitled to one copy of all the publications of the Academy issued subsequent to their

election. Authors of papers shall be entitled to twenty extra copies of their individual papers.

XVIII. SALE OF REAL ESTATE.

The property conveyed to The Academy of Science of St. Louis on the eighteenth day of March, 1903, by Edgar R. Hoadley and Lavinia L. Hoadley, as a gift from Mrs. Eliza McMillan and William N. McMillan, shall not be mortgaged or voluntarily encumbered by the Academy of Science; and the said property shall not be sold, except with the consent of two-thirds of the members of the Academy of Science, obtained by letter-ballot, in such manner as may be prescribed by the Council; and, when sold, the proceeds of the sale or so much thereof as may be necessary, shall be used to provide a suitable location and building for the use of The Academy of Science of St. Louis.

XIX. AUTHORITY.

On all points of order and procedure, not provided for in the Constitution and By-Laws, *Robert's Rules of Order* shall be the authority.

XX. AMENDMENTS.

These By-Laws may be amended by two-thirds vote of all the members present at any regular meeting, provided notice of the proposed amendment shall have been mailed to every member at least one week before the vote thereon is taken.

ABSTRACT OF HISTORY.

ORGANIZATION.

The Academy of Science of St. Louis was organized on the 10th of March, 1856, in the hall of the Board of Public Schools. Dr. George Engelmann was the first President.

CHARTER.

On the 17th of January following, a charter incorporating the Academy was signed and approved, and this was accepted by a vote of the Academy on the 9th of February, 1857.

OBJECTS.

The act of incorporation declares the object of the Academy to be the advancement of science and the establishment in St. Louis of a museum and library for the illustration and study of its various branches, and provides that the members shall acquire no individual property in the real estate, cabinets, library, or other of its effects, their interest being merely usufructuary.

The constitution as adopted at the organization meeting and amended at various times subsequently, provides for holding meetings for the consideration and discussion of scientific subjects; taking measures to procure original papers upon such subjects; the publication of transactions; the establishment and maintenance of a cabinet of objects illustrative of the several departments of science and a library of works relating to the same; and the establishment of relations with other scientific institutions. To encourage and promote special investigation in any branch of science, the formation of special sections under the charter is provided for.

MEMBERSHIP.

Members are classified as active members, corresponding members, honorary members and patrons. Active membership is limited to persons interested in science, though they need not of necessity be engaged in scientific work, and they alone conduct the affairs of the Academy, under its constitution. Persons not living in the city or county of St. Louis who are disposed to further the objects of the Academy, by original researches, contributions of specimens, or otherwise, are eligible as corresponding members. Persons not living in the city or county of St. Louis are eligible as honorary members by virtue of their attainments in science. Any person conveying to the Academy the sum of one thousand dollars or its equivalent becomes eligible as a patron.

Under the By-Laws, resident active members pay annual dues of six dollars. Non-resident active members pay annual dues of three dollars only. Patrons and honorary and corresponding members are exempt from the payment of dues. Each patron, honorary member, and active member not in arrears is entitled to one copy of each publication of the Academy issued after his election.

Since the organization of the Academy, 1,324 persons have been elected to active membership, of whom, on December 31, 1913, 304 were carried on the list. Six patrons, Mr. Edwin Harrison, Mrs. Eliza McMillan, Mr. William Northrop McMillan, Mr. Henry W. Eliot, Mr. William Keeney Bixby and Mr. Edward Mallinckrodt, have been elected. Elections to honorary membership number 14 (page vi), and 225 persons (Vol. X., p. xii) have been elected to corresponding membership.

OFFICERS AND MANAGEMENT.

The officers, who are chosen from the active members, consist of a President, two Vice-Presidents, Recording and Corresponding Secretaries, Treasurer, Librarian, three Curators and two Directors. The general business

management of the Academy is vested in a Council composed of the officers.

The office of President has been filled by the following well-known citizens of St. Louis, nearly all of whom have been eminent in some line of scientific work: George Engelmann, Benjamin F. Shumard, Adolphus Wislizenus, Hiram A. Prout, John B. Johnson, James B. Eads, William T. Harris, Charles V. Riley, Francis E. Nipher, Henry S. Pritchett, John Green, Melvin L. Gray, Edmund A. Engler, Robert Moore, Henry W. Eliot, Edwin Harrison, Adolf Alt, Calvin M. Woodward, and William Trelease.

MEETINGS.

The regular meetings of the Academy are held at its building, 3817 Olive Street, at 8:15 o'clock, on the first and third Monday evenings of each month, a recess being taken between the meeting on the first Monday in June and the meeting on the third Monday in October. These meetings, to which interested persons are always welcome, are devoted in part to the reading of technical papers designed for publication in the Academy's Transactions, and in part to the presentation of more popular abstracts of recent investigation or progress. From time to time public lectures, calculated to interest a larger audience, are provided for in some suitable hall.

The following dates for regular meetings for the year 1914 have been fixed by the Council:

Jan	Feb	Mar	April	May	June	Oct	Nov	Dec
5	2	2	6	4	1		2	7
19	16	16	20	18		19	16	21

LIBRARY.

After its organization, the Academy met in Pope's Medical College, where a creditable beginning had been made toward the formation of a museum and library, until May, 1869, when the building and museum were destroyed by fire, the library being saved. The library now contains about 18,500 books and 16,000 pamphlets, and is open during certain hours of the day for consultation by members and persons engaged in scientific work.

PUBLICATIONS AND EXCHANGES.

Twenty-two octavo volumes of Transactions have been published since the organization of the Academy, and widely distributed. Two quarto publications have also been issued: one from the Archaeological Section, being a contribution to the archaeology of Missouri, and the other a report of the observations made by the Washington University Eclipse Party of 1889. The Academy now stands in exchange relations with 420 institutions or organizations of aims similar to its own.

MUSEUM.

After the loss of its first museum, in 1869, the Academy lacked adequate room for the arrangement of a public museum, and, although small museum accessions were received and cared for, its main effort, of necessity, was concentrated on the holding of meetings, the formation of a library, the publication of worthy scientific matter, and the maintenance of relations with other scientific bodies.

The Museum is at present located on the first floor of the Academy Building and has in it a number of specimens illustrating the various branches of natural science, among which may be mentioned the Yandell Collection of fossils, a collection of some 600 exotic butterflies, a collection of Mound Builder pottery and skulls from near New Madrid, Mo., and a collection of 25 meteorites. Our material forms but a nucleus of a museum which the Academy hopes to establish—a museum which we trust will be of benefit to the public and to the educational institutions of the city.

RECORD.

From January 1 to December 31, 1913.

The following list of papers were presented at the meetings during this period:

January 15, 1913:

S. Bent Russell.—Demonstration and Design of Apparatus to Simulate the Working of Nervous Discharges.
(Published in Journal of Animal Behavior, Vol. 3, No. 1, 1913.)

J. L. Van Ornum.—Experiments on the Pointing of Pressure Tubes, to Eliminate Velocity Effects, in Water Pipes.

F. E. Nipher.—The Strength of a Steel Magnet Dependent upon its Electric Potential.

February 3, 1913:

Moses Craig.—Plant Improvement by Selection.

C. H. Turner.—An Apparent Reversal of the Light Responses of the Common Roach.

F. E. Nipher.—The Strength of a Steel Magnet Dependent upon its Electric Potential.

February 17, 1913:

F. E. Nipher.—Effect of Electrification of Air on its Magnetic Permeability.

LeRoy McMaster.—The Preparation and Properties of Some Ammonium Salts of Organic Acids.
(Published in American Chemical Journal, Vol. XLIX, No. 4, 1913.)

Leo Loeb.—Some Biological Aspects of Tumor Investigation.

March 3, 1913:

F. E. Nipher.—The Behavior of the Magnetic Needle on Windy and Calm Days.
(Published in Transactions, Academy of Science of St. Louis, Vol. XXII, No. 2, 1913.)

R. A. Hall.—Fixation of Atmospheric Nitrogen.
S. S. Knight.—Some Microscopic Observations upon the Segregation of Impurities in Carbon-Iron Alloys.
R. J. Terry.—The Development of the Cranium in Mammals. II.

March 17, 1913:
E. G. Payne.—Social Effects of Some Recent Child Labor Legislation in Missouri.
C. M. Gill.—A Possible Explanation of the 'Inferno' at Fern Lake near Estes Park, Colorado.
F. E. Nipher.—The Effect of Wind on the Magnetic Needle.

April 7, 1913:
G. O. James.—How Worlds are Formed.
Julius Hurter.—Cobras.

April 21, 1913:
B. M. Duggar.—The Significance of Color in Plants.
C. A. Todd.—Observations on the Migratory Flight of a Butterfly.
R. A. Hall.—Preparation of Neutral Tri-Ammonium Citrate.

May 5, 1913:
M. E. Wilson.—The Geology of the Meramec Highlands Region.
C. A. Todd.—Further Observations on the Migratory Flight of a Butterfly.

May 19, 1913:
Geo. T. Moore.—Speculations on the Origin of Life.

June 2, 1913:
Hermann von Schrenk.—Recent Epidemic Appearance of Termites in St. Louis Houses.
H. M. Whelpey.—The Shrunken Human Heads of Bolivia.

October 20, 1913:

F. E. Nipher.—Variations in the Earth's Magnetic Field.

(Published in Transactions, Academy of Science of St. Louis, Vol. XXII, No. 4, 1913.)

H. M. Whelpey.—Problems in American Archæology.

November 3, 1913:

J. L. Van Ornum.—Forests and Floods.

November 17, 1913:

F. E. Nipher.—Uniform Motion of a Load upon an Inclined Plane.

W. H. Chenery.—The Problem of Organization; a Criticism of Theodor Ostwald's *Der Energetische Imperativ.*

C. A. Waldo.—A New Application of Electricity to the Production of Musical Tones.

December 1, 1913:

J. M. Greenman.—The Coastal-Plain Flora of Mexico.

W. H. Roever.—The Curve of Light on the Dome of the New Roman Catholic Cathedral.

(Published in American Mathematical Monthly, Vol. XX, No. 10, Dec., 1913.)

December 15, 1913:

J. A. Warner.—The Process of Manufacturing Anti-Toxins.

Meeting of January 6, 1913.

The Academy of Science of St. Louis met in the Academy Building, 3817 Olive Street, at 8 p. m., January 6, 1913; President Engler in the chair; attendance 20.

The President delivered his address as President of the Academy for the year 1912.

The Treasurer's report for the year 1912 was submitted.[3]

The report of the Curators for 1912 was read.[4]

The report of the Librarian for 1912 was presented.[5]

[3] Transactions, Vol. XXI, page lii.

[4] Transactions, Vol. XXI, page lii.

[5] Transactions, Vol. XXI, page lii.

The Nominating Committee reported the results of the election of officers for 1913, as follows:

President	E. A. Engler
First Vice-President	F. E. Nipher
Second Vice-President	A. E. Ewing
Recording Secretary	J. A. Drushel
Corresponding Secretary	Geo. O. James
Treasurer	H. E. Wiedemann
Librarian	Wm. L. R. Gifford
Curators	Julius Hurter
	Hermann von Schrenk
	Philip Rau
Directors	Adolf Alt
	H. M. Whelpley

The death of Dr. Geo. C. Crandall and of Mr. Irwin Z. Smith, active members, and of Professor G. C. Broadhead, corresponding member, was reported.

January 20, 1913.

President Engler in the chair; attendance 24.

The following donations to the Museum were reported:

R. F. O'Neal..European Starling (*Sturnus vulgaris*).
..Louisiana Centennial Medal, 1812-1813.

Mr. S. Bent Russell read a paper on "Demonstration and Design of Apparatus to Simulate the Working of Nervous Discharges."

First Mr. Russell explained why it is that an animal provided with muscles and a nervous system grows wiser with experience. For example, if an animal makes a movement that is followed by pain it will learn to refrain from the movement. In the same way he explained why the horse learns to jump at the crack of the whip without waiting for the blow; why the animal learns to avoid certain obstacles by turning certain ways; why a movement that is followed by a form of satisfaction becomes habitual; why the movements of certain muscles, after the proper experience, habitually occur together.

The explanation showed that all these actions are due simply to the nervous discharge following the channel that is most open at the time. The more frequently the channel has been used and the more recently, the more open it will be. The point was then made that if the channel is provided with two sensory endings and conditions are such that the two endings are excited in succession from time to time, it will become much more open, and movements will be made accordingly.

Thus experience determines development and variable responses are accounted for.

The theory thus given was supplemented by a brief description with lantern slides and sketches of a practical device which operates on something the same principle. The apparatus described is a hydraulic regulating system. The important parts are: 1st, a transmitter or triple slide valve with a timing attachment; 2nd, a measuring or balancing device governing a hydraulic cylinder or motor; 3rd, a system of key rods connected so that each key rod controls one or more transmitters and on the other hand each transmitter is controlled by one or more key rods.

The speaker demonstrated that the apparatus will respond to signals as a nervous system does, i. e., the responses are determined by previous experience. In other words, the speaker showed a practical arrangement of valves, pipes, springs, ratchets, cranks, pistons, etc, that will respond to signals and make movements like the nerves and muscles in an animal of some intelligence. The mechanism can be trained, can acquire habits, will move forward or back at a given signal, according to experience, will make one, two or three responses to a given signal, according to experience.

Professor J. L. Van Ornum spoke on "Experiments on the Pointing of Pressure Tubes, to Eliminate Velocity Effects, in Water Pipes," with especial reference to the auxiliary tubes of Pitometers.

For a long time it was assumed and still seems to be supposed by many, judging from statements in books and periodicals, that the pointing of a pitot tube to give a zero velocity indication when placed in a fluid stream should be at an angle of ninety degrees from the direction of flow; but this is not true. To the members of this Academy the most familiar proof of the fact is contained in paper No. 3, of Vol. XVI, of its Transactions, in which Professor Nipher states that a pitot tube in a current of air shows a negative velocity head (when pointed at an angle of ninety degrees from the direction of the air current) greater in amount than the maximum positive velocity head when directly facing the current of air; and that the angle of pointing to show a zero velocity head in air is sixty degrees.

The thesis experiments of Messrs. Patton and Wallace in the Washington University hydraulic laboratory nearly three years ago and later ones by Mr. Hooper, as well as Dr. Schuster's experiments at Dresden published about two years ago, are definite indications that the same facts are true in currents of water.

Among the other considerations discussed in the above mentioned theses is one perhaps more important than that just mentioned. It is the fact that, unless the pitot tubes have the theoretically required perfectly thin edge, the angle is increased from the sixty degree angle to one of greater size. When a cone, with its base coinciding with the plane of the mouth of the pitot tube, is used, its angle is greater than

sixty degrees in proportion to the increase of diameter of the base; and it does not require a very great expanse of mouth area to give an angle of ninety degrees, the one first assumed.

This conclusion has a particular point of interest in the fact that it indicates that the usual piezometer attachment to pipes for measuring pressure heads is correct, their normal direction having no connection with the sixty degree angle already discussed for the thin-edged pitot tubes.

Professor F. E. Nipher stated that he had obtained results in recent experiments which seem to indicate that the strength of a steel magnet depends upon its electric potential.

Mr. John E. Montague was elected to membership.

February 3, 1913.

President Engler in the chair; attendance 15.

The following donations to the Library were reported:

J. J. Kessler.....A pamphlet on The Nitrile of Fumaric Acid.
A. S. Langsdorf..Two volumes of Science.

Mr. Moses Craig read a paper on "Plant Improvement by Selection."

Mr. Craig briefly traced the history of plant breeding, outlining the Darwinian and De Vriesian views of the origin of new forms, with Mendel's law of character segregation. The importance of hybridization in hastening variation was mentioned with methods of inbreeding and methodical selection. He then gave many practical directions for improving our pomaceous, cereal and vegetable crops.

Dr. Chas. H. Turner read a paper on "An Apparent Reversal of the Light Responses of the Common Roach."

The paper discussed a series of experiments conducted with the common roach (*Periplaneta orientalis*) for the purpose of seeing if the negatively phototropic animal could be trained to refuse to enter a specific dark place; and, if that proved possible, to experimentally analyze the behavior. The electrical punishment method, devised by Professor Yerkes, in his study of the dancing mouse, was used.

According to the speaker this method has been used only once before in the study of insect behavior; that was by Mr. Szymanski[6] in studying the responses of several larval male cockroaches. A resumé of

[6] Journal of Animal Behavior, 2:81-90. 1912.

Mr. Szymanski's paper was given and the statement made that Mr. Szymanski did not experimentally determine whether the refusal to enter the dark chamber was the reversal of a negative phototropism or an example of learning, by means of associative memory, to avoid a disagreeable dark place.

A pen containing one dark chamber and one lighted chamber, or a pen containing one dark chamber and two lighted chambers, was placed on a platform composed of copper strips so arranged that an electric current could be sent through them at will. A marked roach was placed in a lighted chamber of one of the pens. If it was the roach's first time in the pen, it would immediately rush into the darkness. The current was then turned on, the shock of which would cause the roach to rush back into the light. Thereafter it would enter the dark chamber more cautiously. Each time it received a shock. After a while it could not be induced to enter the dark chamber. These experiments were conducted with roaches of both sexes and of several different ages.

The speaker said he believed the majority of the students of comparative psychology would call the above described behavior a reversal of a negative phototropism; but he insisted that it was just as logical to conclude that the roach, by means of associative memory, had learned to avoid a specific dark place because of certain disagreeable associations.

He further stated that he did not consider a learning curve a safe criterion for interpreting behavior, and based his statement upon the fact that Dr. Carr in experimenting with human beings in a maze obtained learning curves which, by the usual mode of interpretation, indicated a type of intelligence lower than that of the rat.

He also objected to adopting Professor Lloyd Morgan's method of selecting the simpler of two equally plausible solutions of an example of animal behavior. Dr. Turner insisted that, in such cases, the behavior should be experimentally analyzed; or else one should say frankly that the problem has not been solved.

In this case the behavior was analyzed by the following experiment: A roach which had thoroughly learned to refuse to enter the dark chamber of a pen resting upon the copper strips was transferred from that pen to a similar one resting on a different surface. In each case the roach would immediately rush into the dark chamber. The roach was then returned to the lighted portion of the pen resting on the copper strips. It then refused to enter the dark chamber. This was found to be true of numerous normal roaches of several different ages and of both sexes. Antennaeless roaches would enter the dark chamber under both conditions.

CONCLUSIONS.

1. By means of electric shocks roaches can be trained to avoid entering a specific dark place. This is not a reversal of a phototropism; but the result of learning to avoid a specific dark place because of certain disagreeable experiences associated with it.

2. Generally speaking, male roaches learn more quickly than female and young roaches are more apt than adults; but there are marked individual exceptions to this.

3. In the ability to learn and to retain what they have acquired roaches exhibit marked individuality.

4. Roaches that have acquired the habit of refusing to enter a dark place do not lose the habit when they moult.

5. Roaches that have learned to respond in the manner described continue to respond in that way even when several days elapse between experiments.

6. During sickness and just prior to death the retentiveness of the roach is much impaired.

Professor F. E. Nipher stated that he had recently obtained results which confirm his previous conclusion, that the strength of a steel magnet depends upon its electric potential. He has found this to be the case even when the magnet composed of a layer of fine steel wire is wholly enclosed in a covering of tin-foil.

February 17, 1913.

President Engler in the chair; attendance 36.

The following donations to the Library were reported:

D. L. Harris..Five pamphlets on the subject of rabies.
A. S. Pearse..Four pamphlets on crabs.

Professor F. E. Nipher addressed the Academy on "Effect of Electrification of Air on its Magnetic Permeability."

Professor Nipher stated that he had recently found that when a steel magnet is insulated and connected to either terminal of an influence machine, the other terminal being grounded, all points in the field of the magnet show an increase in magnetic intensity. There is an apparent increase in the magnetic moment of the magnet. This is really due to an increase in the permeability of the surrounding air.

The magnet thus acted upon was one of two deflecting magnets, placed on opposite sides of a magnetic needle suspended from a silk fiber, within a metal cylinder. The motion of the needle was observed by means of a telescope and scale, through a small opening in the metal shield, which was closed by a sheet of glass covered with wire gauze.

One of the deflecting magnets is put in contact with the influence machine. All disruptive effects are to be avoided. The needle shows a gradual deviation from the magnetic meridian, amounting to about four minutes of arc. This result is obtained even when the magnet is

wrapped in tin-foil, but not when it is within a large mass of cotton batting.

When the air around the charged magnet is disturbed by means of a palm-leaf fan, the deflection of the needle is not less than 15 seconds; its amplitude of vibration may be gradually increased, by operating the fan during alternate semi-vibrations. In this way the angle of vibration has been increased to about four degrees of arc. In a similar manner it can be quickly brought to rest.

This result seems to indicate that the electrified molecules of air behave somewhat like iron filings in the field of the magnet.

Arrangements are being made to place the deflecting magnets in adjoining rooms. The electrified magnet being placed between two large sheets of glass, may make it possible to obtain photographs of the lines of force.

The deviations of the needle here observed are of the same order of magnitude as those due to momentary variations in the magnetic field of the earth.

Professor LeRoy McMaster read a paper on "The Preparation and Properties of Some Ammonium Salts of Organic Acids."

Professor McMaster described a method of preparing the neutral ammonium salts of monobasic and dibasic organic acids, and gave an account of some of the properties of these salts. The method consists, briefly, in dissolving the organic acids in absolute alcohol or ether and passing dry ammonia gas into the solution. By this method were easily prepared the neutral ammonium salts of succinic, tartaric, ortho and meta-phthalic acids, propionic, iso-butyric and benzoic acids. The neutral salts of malonic, malic and cinnamic acids were prepared with some difficulty. Analyses of the prepared salts were given and proved the compounds to be neutral.

Dr. Leo Loeb presented a communication entitled "Some Biological Aspects of Tumor Investigation."

Weismann stated that Protozoa and germ cells of metazoa are potentially immortal while the somatic cells of metazoa are mortal. As far as the Protozoa are concerned his statement was controverted by Maupas, R. Hartwig, Calkins and others. The recent experiments of Henriquez and especially of Woodruff make it, however, very probable that his conclusion was essentially correct. As far as the somatic cells of metazoa are concerned, Weismann's conclusion was not warranted by facts, the evidence pointing merely to the conclusion that somatic cells can usually not reproduce the whole organism. The writer first pointed out in 1901 that facts established through experimental tumor investigation made it very probable that tumor cells are potentially immortal—as much as Protozoa and as germ cells. And a few years later he concluded further that, inasmuch as tumor cells are merely ordinary

somatic cells living under special conditions, the proof has been supplied—as much as that can be done—that ordinary somatic cells are potentially immortal. He also pointed out that this conclusion could still further be confirmed by serial transplantations of ordinary tissues in animals of various ages. He began such experiments a number of years ago and is continuing this work now under more favorable conditions.

Experimental tumor investigation has furthermore demonstrated that many somatic cells have a potential power to proliferate, which appeared almost unthinkable until recent years. One single epithelial or connective tissue cell being potentially able to produce masses of cells which surpass many times the number of cells composing a whole animal of the same species.

Germ cells show definite rhythms. Certain Protozoa also possess definite rhythms, as shown by Maupas, R. Hertwig, Calkins and others. Bashford and Calkins maintained that tumors also possessed definite rhythmic changes. Investigations carried out by M. S. Fleisher in our laboratory show such rhythms do not exist in the case of tumors. If they exist in the case of other somatic tissues, they are not primary attributes of these tissues, but due to secondary mechanisms.

The death of Mr. Gilbert G. Morrison was announced.

March 3, 1913.

President Engler in the chair; attendance 43.

The following donations to the Library were reported:

LeRoy McMaster..Two pamphlets on the preparation of ammonium salts of organic acids.

Professor F. E. Nipher gave some further observations on the behavior of the magnetic needle on windy and calm days.

Dr. R. A. Hall spoke on the "Fixation of Atmosperic Nitrogen."

Dr. R. J. Terry gave some of the results of his study of "The Development of the Cranium in Mammals. II."

Dr. Terry stated that Weiss's study of the occipital region of embryos of white rats revealed the fact that the dens epistrophei in these animals is composed of two elements, the one generally recognized as comparable with a centrum for the atlas, the other lying cephalad of this and forming the extremity of the dens. The latter is derived by independent chondrification in the tissue about the notochord cephalad of the atlas and where the former crosses the dorsal surface of the basal plate of the cranium. Weiss regarded this cephalic element as representing the centrum of an occipital vertebra or a proatlas.

The presence of an element in the dens epistrophei of cat embryos has been observed developing cephalad of the component identified as the centrum of the atlas and extending upon the basal plate of the cranium. This component is derived from the mesenchyma which, in the form of a cone traversed by the notochord, extends from the level of the atlas cephalad upon the basal plate and there lies in a deep median groove. Chondrification in this part of the dens occurs later than in that part related to the atlas, but the two processes appear not to be entirely distinct.

Mr. S. S. Knight presented a paper entitled "Some Microscopic Observations upon the Segregation of Impurities in Carbon-Iron Alloys."

This paper was accompanied by some seventy-five slides, showing original work done in the field of metallography, and detailed largely the isolation and description of the impurities found in the form of phosphides, sulphides, silicides and cuprides as they occur in cast material, which has had no work done upon it.

March 17, 1913.

President Engler in the chair; attendance 31.

Dr. E. G. Payne addressed the Academy on "Social Effects of Some Recent Child Labor Legislation in Missouri."

The law considered was section 1716, Revised Statutes of Missouri, limiting the labor of children between the ages of fourteen and sixteen years to eight hours per day. The effect of the law is to exclude laborers under sixteen from factory employment, because of the inability of managers to use with profit laborers working on two schedules. An examination of available data relating to school attendance showed that laborers excluded are not in school. Also that the law has not tended to deter children affected by the law from leaving school when they become fourteen. The children between fourteen and sixteen are, therefore, in "blind alley" vocations; i. e., working as newsboys, errand boys, office boys, street vendors, drivers, delivery boys, etc., and upon the streets, unemployed. In so far as the work of the children is necessary for the family support the result has been bad, as there has resulted keen competition for the positions that are now open to children who are compelled to work, but are excluded from factory employment. A study of data gathered by the Bureau of Labor, the Chicago School of Civics and Philanthropy, and the records of the Juvenile Court in St. Louis showed that tendency to crime among children is most marked among those engaged in the "blind alley" vocations and among the unemployed. These data led to the conclusion that the law has resulted in serious evil consequences and that supplementary legislation is necessary to make the law effective.

Mr. Charles M. Gill presented "A Possible Explanation of the 'Inferno' at Fern Lake near Estes Park, Colorado."

The "Inferno" lies on the shore of Fern Lake, fourteen miles southeast of Estes Park, Colorado, and at the head of the canyon of the Big Thompson River.

The feature in question consists of a mass of rock fragments, four hundred feet in length and sixty in breadth, arranged so as to form an elongated oval depression. The rim consists of granite masses from four to twelve feet in diameter. The size of the boulders grades down to a diameter of about a foot at the bottom of the pit twenty feet below.

The topography of the entire region is glacial. The basin of Fern Lake is glacially scooped, and a moraine has raised the basin rim on the northeast side.

The hypothesis consists of three parts:—

1st. That the source of the material is the cliffs above the formation. This is borne out by the identity of the granites and the scarred cliff.

2nd. That the fall of material was probably due to earthquake. In the canyon below and in the foot of the cliffs in this region are other rock masses of about the same degree of weathering.

3rd. That the peculiar arrangement of the rocks results from the fall of the mass upon a shallow glacier then filling the lake basin. When the ice melted near the cliff base, other masses were released. Upon the complete melting the larger fragments are found at the outer edge as is usual in glacial kettle holes.

The degree of weathering is comparable with that of glaciated surfaces of the same granite in this region.

The absence of even a trace of vulcanism precludes it as a cause.

Professor F. E. Nipher made some remarks on the effect of wind on the magnetic needle.

April 7, 1913.

President Engler in the chair; attendance 69.

The following donations to the Museum and Library were announced:

H. M. Whelpley ..Section of a fossil tree trunk from the Petrified Forest, Arizona.

Otto Widmann....A pamphlet on the birds of Estes Park.

Dr. G. O. James gave an illustrated lecture on "How Worlds are Formed."

Dr. James discussed:

1st. Laplace's theory of the formation of the Solar System.

2nd. See's capture theory of the Planetary Systems.

3rd. The heavenly bodies, especially the earth, as the home of living beings.

4th. Radiation and constitution of the sun.

5th. Dying of the sun. Origin of nebulae.

6th. Distribution of life through the universe.

Mr. Julius Hurter read a paper on "Cobras."

April 21, 1913.

President Engler in the chair; attendance 35.

The following donation to the Library was reported:

LeRoy McMaster..A pamphlet on the preparation and properties of the ammonium salts of some organic acids.

Dr. B. M. Duggar addressed the Academy on "The Significance of Color in Plants."

Dr. C. A. Todd read a paper on "Observations on the Migratory Flight of a Butterfly."

Anosia plexippus (Monarch) is believed not to hibernate in the colder parts of the United States, and, consequently, must migrate to escape frost. It migrates with the birds and much in the same fashion. *A. plexippus* is supposed to winter in the Gulf States. Butterflies, according to reasonable interpretation of their lives, are largely, if not altogether, automatic. The autumn migration of *A. plexippus* over great distances, always maintaining a fixed direction; when temporarily diverted or checked, with mechanical promptitude resuming that direction (most remarkably so in a flight specially described in the paper), all this would lead logically to assume the operation of a force wholly external, a force that compels the insect to continue in a fixed direction of line of flight, just as the magnetic needle, after having been disturbed from a state of rest, must resume its appointed place. The present trend of science aiming to obliterate the chasm hitherto supposed necessarily to exist between the natures of animate and inanimate things, would justify such comparison. In other words, we seem justified in assuming that the migratory flight of *A. plexippus* is purely automatic, and possibly due to "magnetic" influence.

As this flight closely resembles that of birds, if it be not identical in the main features, the same theory is applicable to both.

Owing to the lack of universal and systematic observation of the flight, its full course and extent has not been mapped out. Such observations will require united action on the part of all scientific bodies. Action in that direction should be initiated at Washington and might need to be extended over several years according to results.

Professor Robert A. Hall reported that he had succeeded in preparing Neutral Tri-Ammonium Citrate.

Neutral Tri-Ammonium Citrate was prepared by passing an excess of dry ammonia gas into a well cooled solution of the water free citric acid in an anhydrous solvent.[1] The yield is quantitative. Tri-ammonium citrate thus prepared is a stable, white, crystalline substance, not hygroscopic and not affected by the CO_2 of the atmosphere. It dissolves readily in water and the freshly prepared solution is neutral to sensitive litmus, azo-litmin, corallin, methyl red, etc. Rigorous analyses of both the ammonia and the citrate content of the salt show it to be the tri-ammonium citrate. Further investigation of its physical-chemical properties are being made.

As the method of preparation is simple and inexpensive and the yield good it is evident that this means a solution of the difficult problem of the fertilizer chemist in the preparation of neutral ammonium citrate solution for the determination of the citrate insoluble phosphoric acid in fertilizer analysis.

May 5, 1913.

President Engler in the chair; attendance 29.

The following donations to the Museum and Library were reported:

Edward Evers..One volume of Naturwissenschaftliche Rundschau and two volumes of Globus. Fourteen pieces of Zuni pottery.

Professor M. E. Wilson gave an illustrated lecture on "The Geology of the Meramec Highlands Region."

Dr. Chas. A. Todd, who read a paper at the preceding meeting on "Observations on the Migratory Flight of a Butterfly," exhibited fresh specimens of returning Monarchs (*Anosia plexippus*) badly battered, and bleached in color, showing evidence of travel and long exposure to weather.

May 19, 1913.

President Engler in the chair; attendance 51.

Dr. Geo. T. Moore addressed the Academy on "Speculations on the Origin of Life."

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[1] This body was first prepared by this method two years ago at the time of the investigation of the Conductivity Method of Preparing Neutral Ammonium Citrate Solutions but a press of other research prevented its analysis and complete identification until the present time.

June 2, 1913.

President Engler in the chair; attendance 37.

The following donation to the Library was announced:

Julius Hurter..Proceedings of the Seventh International Zoological Congress.

Dr. Hermann von Schrenk spoke on "Recent Epidemic Appearance of Termites in St. Louis Houses."

Dr. H. M. Whelpey gave an illustrated account of "The Shrunken Human Heads of Bolivia."

Messrs. C. S. Mepham and J. Max Wulfing were elected to membership.

The death of Mr. Julian Bagby and Mr. Geo. W. Letterman was reported.

George Washington Letterman.

With the death of Mr. George W. Letterman in Allenton, Mo., on May 28, 1913, there passed one of the few persons who have worked upon the botany of St. Louis and vicinity during their whole life time. His herbarium represents the flora of St. Louis county probably better than any other in existence.

While Mr. Letterman had worked especially in Missouri, he was an authority on the plants of the region included in eastern and northern Texas, Louisiana, Arkansas and Oklahoma.

George W. Letterman was born in Pennsylvania seventy-two years ago. While at State College in Center County, the Civil War broke out and young Letterman enlisted as a private, serving until the end of the war, when he was mustered out of the service with the rank of captain of volunteers.

He crossed the plains to New Mexico in 1866, returned to Pennsylvania, and again going west to Kansas with the idea of farming in that state, he settled finally in 1869 in Allenton, Mo., a hamlet about thirty miles west of St. Louis.

Here Mr. Letterman taught school for many years also serving as superintendent of schools in St. Louis county.

Shortly after settling in Allenton, Mr. Letterman met August Fendler, the botanist, who had a farm in that neighborhood. This meeting stimulated his interest in plants, especially in trees. For Dr. Engelmann Letterman made large collections of plants in the neighborhood of Allenton, with many notes on the oaks and hickories.

In 1880 he was appointed special agent of the Census Department of the United States to collect information about the trees and forests of Missouri, Arkansas, western Louisiana and eastern Texas. Later he collected specimens from the same region for the Jesup Collection of

North American woods in the American Museum of Natural History in New York. The name *Lettermani* commemorates his numerous discoveries in these little known regions.

October 20, 1913.

President Engler in the chair; attendance 46.

The following donations to the Museum and Library were reported:

A. F. Onderdenk..Fifteen volumes of the Scientific American Supplement.

G. R. Agassiz.....Letters and Recollections of Alexander Agassiz with a sketch of his life and work.

Professor F. E. Nipher addressed the Academy on "Variations in the Earth's Magnetic Field."

Dr. H. M. Whelpley gave an illustrated lecture on "Problems in America Archæology.".

The death of Mr. Adolphus Busch, of Mr. Moses Craig, of Mr. Chas. H. Huttig, of Mr. Elias Michael, and of Dr. William Taussig was announced.

November 3, 1913.

President Engler in the chair; attendance 26.

Professor J. L. Van Ornum addressed the Academy on "Forests and Floods."

Professor Van Ornum outlined the complexity of the relation between rainfall and runoff. He then indicated that, while exceptions occur and greater differences exist, the general tendency of forests is to somewhat equalize and increase the rainfall locally, to reduce evaporation from the soil, to prolong the melting of snow, to retard surface flow and to prevent the erosion of soil in hilly and mountainous country. Yet the essential question is whether this tendency is potent enough to be important. The impossibility was shown of deductively determining the quantitative value of the forest influence, with any approach to satisfactory results, by attempting the evaluation of the different factors contributing to that influence.

Then four investigations were reviewed, in three of which no appreciable effect of extensive change in forest cover could be detected in the runoff phenomena, and in one of them the effect was apparent.

The conclusion was reached that the forest influence is sometimes considerable on watersheds of small area, but that it is slight on those of moderate extent and generally is entirely imperceptible in its effect on flood flow in the main rivers of large drainage basins.

Messrs. Jesse M. Greenman and Albert E. Taussig were elected to membership.

DECEMBER 1, 1913.

President Engler in the chair; attendance 30.

Dr. J. M. Greenman addressed the Academy on "The Coastal-Plain Flora of Mexico."

Professor Wm. H. Roever spoke on "The Curve of Light on the Dome of the New Roman Catholic Cathedral."

Dr. R. J. Terry, Mr. Otto Widman and Mr. Lewis M. Dougan were elected a committee to nominate officers for 1914.

In accordance with Article XX of the By-Laws the following changes in Articles XV and XVII were voted upon and unanimously adopted:

By-Law XV, entitled Initiation Fees and Dues, which read:

> "Resident active members shall pay an initiation fee of five dollars, and annual dues of six dollars, payable at the beginning of each year. Non-resident active members shall pay an initiation fee of five dollars and annual dues of one-half the dues for resident active members, payable at the beginning of each year."

to read as follows:

> "Annual dues shall be paid at the beginning of each year. Resident active members shall pay annual dues of six dollars, and non-resident active members shall pay annual dues of three dollars. There shall be no initiation fee."

By-Law XVII, entitled Publications, which read:

> "Patrons and all active members not in arrears shall be entitled to one copy of all the publications of the Academy issued subsequent to their election. Authors of papers shall be entitled to twenty extra copies of their individual papers."

to read as follows:

> "Patrons, honorary members, and all active members not in arrears shall be entitled to one copy of all the publications of the Academy issued subsequent to their election. Authors of papers shall be entitled to twenty extra copies of their individual papers."

Mr. W. F. Monfort was elected to membership.

December 15, 1913.

President Engler in the chair; attendance 34.

The following donations to the Museum were reported:

Julius Hurter..27 species of Missouri snakes.
8 species of Missouri lizards.
8 species of Missouri turtles.
10 species of Missouri toads and frogs.
15 species of Missouri salamanders.

Dr. J. A. Warner gave an illustrated lecture on "The Process of Manufacturing Anti-Toxins."

The following report of the Nominating Committee was read:

St. Louis, Mo., Dec. 15, 1913.

To The Members, Academy of Science,
St. Louis, Mo.

Gentlemen: Your committee, elected Monday, December 1st, to nominate officers for the year 1914, beg to submit the following report of nominations:

For President	Edmund A. Engler.
For First Vice-President	Francis E. Nipher.
For Second Vice-President	George T. Moore.
For Recording Secretary	Charles H. Danforth.
For Corresponding Secretary	George O. James.
For Treasurer	H. E. Wiedemann.
For Librarian	Arthur E. Bostwick.
For Curators	Julius Hurter.
	Philip Rau.
	Hermann von Schrenk.
For Directors	Adolf Alt.
	H. M. Whelpley.

Respectfully submitted,
(Signed)
O. Widmann,
L. M. Dougan,
R. J. Terry.

The death of Dr. John Green and of Mr. Thomas D. Witt was reported.

The President appointed Messrs. Hermann von Schrenk, Adolf Alt and Henry Schwarz a committee to draft resolutions on the death of Dr. John Green, past president of the Academy.

Mr. Roy M. Eilers was elected to membership.

REPORTS OF OFFICERS.

Treasurer's Report.

Receipts.

Balance from 1912	$ 348.07
Dues from members	1,570.75
Rent from tenant societies	605.00
Radiators sold	30.00
Academy's Transactions sold	18.70
Interest on balance	30.20
Income from endowment fund	805.56
Total receipts for the year	$3,408.28

Expenditures.

Salaries	$1,352.00
Water license	14.00
Gas, electric light and power	81.47
Fuel	177.73
Telephone	54.15
Printing	769.66
Current expenses	576.07
Remodeling Museum	300.21
Total expenditures for the year	3,325.29
Balance December 31, 1913	82.99
	$3,408.28

Respectfully submitted,

(Signed) H. E. Wiedemann,
Treasurer.

Librarian's Report

The Librarian reported that the accessions to the library for the year 1913 by exchange with 114 home and 306 foreign societies amounted to 671 volumes and 181 pamphlets, by donation 22 volumes and 24 pamphlets, and by purchase 2 volumes.

The Transactions for the year were sent to 114 home and 306 foreign societies.

Report of the Entomological Section.

During the year the section held eight meetings, with an average attendance of ten. The meetings were interesting and instructive, and

all of the papers presented were freely discussed. At most of the meetings specimens were exhibited.

The following papers were presented:

February 26.—An Apparent Reversal of the Light Responses of the Common Roach, by C. H. Turner.

March 16.—The Fertility of the Cecropia Eggs in Relation to the Mating Period, by Phil Rau.

April 30.—Behavior of Certain Wasps, by Phil Rau.
Love Dances of Certain Insects, by C. H. Turner.
Some Remarks on the Life of Miss Murtfeldt, by Hermann Schwarz.

May 29.—Orthogenesis in the Catocala Moths, Hermann and Ernst Schwarz.
A Method of Mounting Butterflies for School Use, by Hermann Schwarz.
Mr. Phil Rau reported that the bag-worm, by constricting the twig caused the death of that portion of the twig which lies beyond the constriction.

June 25.—Differentiation of the Four Families of Butterflies, by Hermann Schwarz.

October 28.—Field Experiments on the Auditory Powers of the Catocala Moths, by C. H. Turner and Ernst Schwarz.

November 25.—Sleeping Habits of Certain Wasps and Butterflies, by Phil Rau.
Review of Some Recent Articles in Insect Behavior, by C. H. Turner.

December 30.—Behavior of the Common Roach on the Maze; with a Brief Resume of the Use of the Maze in Comparative Psychology, by C. H. Turner.

In response to a letter received from Mr. Banks at the June meeting, Mr. J. T. Monell and Dr. C. H. Turner were appointed to serve on a National Committee of Nomenclature.

At the October meeting Mr. Hermann Schwarz reported that, on the 16th of October, 1913, he found on a clothes prop in his yard, a crysalis of *Anosia plexippus*. He was convinced that a Crysalis formed that late in the season would remain such throughout the winter; hence he considers this a hint that this butterfly hibernates in the pupal stage, instead of migrating southward and returning in the spring as is the common belief.

(Signed) Phil Rau, Chairman,
C. H. Turner, Secretary.

A DENTATE FLINT SPADE.

Found in Jefferson County, Missouri (one half natural size).
H. M. Whelpley Collection

DENTATE FLINT SPADES.

At the meeting of the Academy for June 4, 1906,[8] Dr. H. M. Whelpley exhibited a specimen of an Indian flint spade with the edge of the cutting end distinctly dentated by furrows extending back from one-half to one inch on both sides. (See Plate A.)

It is now generally believed that these furrows are the result of the mechanical action of the soil on the flint. Iron spades, hoes and plow shares are sometimes similarly dentated after long use. The dentated flint spades are always polished and show other evidences of much use.

Such spades are comparatively rare, but may occur wherever flint spades are found. Some are made of the light colored Mill Creek, Union County, Illinois, flint and others are from the brown "Tennessee flint."

[8] Transactions Vol. 16. p. CXX.

Transactions of The Academy of Science of St. Louis.

VOL. XXII. No. 1.

THE BIOLOGY OF STAGMOMANTIS CAROLINA.

PHIL RAU AND NELLIE RAU.

Issued March 25, 1913.

THE BIOLOGY OF STAGMOMANTIS CAROLINA.*

Phil Rau and Nellie Rau.

NEW Y
BOTANIC
GARDEN

Introduction.

In attempting to carry on experimental studies on the color and color changes of *Stagmomantis carolina,* we found it necessary to learn more than has hitherto been recorded concerning many of the simple facts of the insect's life history. The following pages embody the knowledge gleaned from three summers' observations on the biology of a good many hundreds of living insects, either free in the garden or in captivity under individual observation.

The insect was first mentioned by Linnaeus in 1763, and after parading under a goodly number of generic and specific names, is today known as *Stagmomantis carolina,* belonging to the order Orthoptera and the family Mantidae.[1]

Distribution.

The family Mantidae is for the most part tropical. Only two species of this genus are at present known in the United States. Our species is found from Florida to Arizona, north to Maryland, Southern Illinois, Missouri, Kansas and Utah.[2] Henshaw (1900) reports it from Rhode Island, and Baker (1905) from California.[3] That the species seems to be gradually working its way northward is evidenced by Rathvon's Report (1862). He says that egg-cases brought from Maryland to Lancaster City, Pa., brought forth their broods and this introduced population persisted in this climate for two or three consecutive seasons, withstanding the temperature of

*Presented before The Academy of Science of St. Louis, May 20, 1912.

[1] Some of the common names are mule-killer, devil's-horse, rear-horse, camel-cricket, devil's-riding-horse, Carolina mantis, praying mantis. For scientific names, see bibliography.

[2] *Fide* Scudder.

[3] Also reported from Mexico, Central and South America. See bibliography.

—10° F. Even here in St. Louis the mantis population survives year after year, apparently unaffected by the occasional extremes of 15° to 20° below zero. Its frequent occurrence in this region was known to Riley in 1868, and during the years 1908-1911, old egg-cases were taken at Meramec Highlands, Mo., Crêve Coeur Lake, Mo., and Forest Park, St. Louis, Mo., while the greatest source of egg-case supply was the board fences in gardens in the southwestern part of this city. Nymphs were also found at Falling Springs, Ill.

Anatomy.

The internal or external anatomy of the insect has never been worked out to any considerable extent, but the following general notes may help to make clear the discussions which follow.

The head is attached to the prothorax by a flexible membrane, which makes it possible for the head to turn almost completely around (Plate I) and the animal when quietly at rest, awaiting its prey, stealthily moves its head in all directions, sometimes holding it in one difficult position for many minutes. The mouth parts are of course formed for biting. Besides the two compound eyes, the head contains three simple eyes. Just how these function or what is their distance of vision is not known, but that they are highly developed for the purpose of distinguishing good prey, on the wing or moving about, is obvious. The insect will eye its victim serenely, sometimes for many minutes, before making the final leap, or back away from distasteful food when offered it.

The prothorax is greatly modified and bears the highly developed pair of forelegs. These appendages are extremely useful to the animal for catching and holding its prey; without these in their highly developed spinal condition, the animal would have no means of offence or defence. Their power is really surprising; the sensation in placing one's finger between them is anything but

pleasant. The two pairs of hind legs are used for carrying the body, while these are held high in the air, ever ready to pounce upon some unheeding prey.

The front coxa is so much enlarged as frequently to be mistaken for the femur (Pl. XVIII, Fig. 1); the femur and tibia are fully supplied with spines, and the five-jointed tarsus is comparatively small. The double row of spines on both femur and tibia are immovable; in addition to these we find in the adults of both sexes three spines, which are movable, located in the middle of the femur and between the two rows, as indicated in Pl. XVIII, Fig. 1, point X. When the tibia is folded against the femur, the large, curved spine at the end of the former fits nicely into the groove of the latter just behind these three movable spines, while these bend nicely inward. This modification is of great advantage to the insect in holding prey. How some of the spines first became movable, and these situated just were they would be of most use, while the others remained inflexible, can be explained most readily, it seems to me, by Natural Selection. This insect has been described and re-described and has had at least eight different names, but nowhere in the literature is mention made of these three spines which are movable. Evidently the descriptions were made from dead material; this shows the distinct advantage of working with living animals.

This high modification of the forelegs is correlated with a similarly modified prothorax (see Pl. XVIII. Fig. 1). It will be seen that the forelegs are attached to this part. How this correlation came about remains a problem of interest. It must be that Natural Selection again, while modifying the appendages to be of use to the insect for long reaching and powerful grasping, harmoniously modified the part that carries them as well. It would certainly be impossible for such an enormous pair of legs to be appended to the usual Orthopteran thorax. On the other hand, what use would economical Nature find in enlarging a part which carries only simple legs, such as

the other members of the group have? In other Orthoptera such as the mole-cricket, we find the forelegs modified for digging; in the grasshopper, cricket and katydid, the hind legs are developed for jumping, and in the roaches all of the legs are specialized for running. In all of these insects the thorax which carries all three pairs of legs is comparatively small, just as is the meso- and metathorax in the mantis, but here the prothorax which carries these forelegs is greatly enlarged. Pl. XVIII, Fig. 1 shows clearly the comparative size of the parts.

To the meso- and metathorax are attached the two pairs of wings and the two hind pairs of legs. When nymphs are caught by the hind legs, they frequently walk away, leaving the limbs in one's hand. These undoubtedly regenerate, since individuals are not infrequently found with one appendage which is smaller than the others. In the younger nymphs, which are fast moving creatures, all six legs are used for locomotion. The adults are slow moving insects, especially so the females; they seldom use the forelegs for walking, but depend upon the hind legs alone for that purpose and keep the forelegs free for grasping prey.

The size and color of the wings differ in the sexes, as the illustrations show. The male can fly for a considerable distance, much in the manner of a locust's flight, but the adult female cannot fly, partly on account of her aborted wings and partly because of being heavily laden with eggs, although she spreads her wings to ease the fall when she drops to a lower surface. The males occasionally come to the lights, but I have yet to observe the first female there.

The function of the cerci is as yet little understood. Sharp (1895, p. 247) thinks that they assist the insect in emerging from the egg-case, and I shall later show how in the adult they may serve as sense-organs in the fashioning of the egg-case.

The Structure of the Egg-Case.

Before taking up the details of the emergence and the nymph forms, it will be well to get clear in mind the architecture of the nest from which they emerge.

The egg-case is built by the mother mantis in the fall and the old insect dies with the approach of winter. The new organism hibernates in the egg-stage, amply protected in the oötheca. The number of individuals normally contained in one of these cases varies from 36 to 140.

Photographs of 39 egg-cases (Pl. XV) will give an adequate idea of their general appearance and variation, while Pl. XVI shows the different sections and the details of architecture. We can best appreciate this picture if we imagine each egg-case to be a dwelling of many rooms (cells), grouped into two rows of suites of four rooms, each suite having a gallery which runs past the end of each room. This gallery has an opening at the top, through which the four occupants of the one suite emerge. The eggs are deposited on end in the cells, and are inclined toward the opening, so that any of the insects can emerge without disturbing the other occupants of the oötheca or of their own particular suite. Of course two insects cannot emerge from one suite at precisely the same time, but one may follow promptly after the other in single file, so very little interference occurs under this system. This arrangement of the cells is clearly shown in the cross-section, Fig. 7-8. The provision of separate galleries and exits for every four insects seems a wonderful economy of Nature.[4] Thus when common environment or common age brings all of the occupants of the nest to maturity and ready for emergence simultaneously, the probable high mortality resulting from crowding around a common exit is avoided. This is why we can examine an egg-case in the early morning and find not a trace of life, return in fifteen minutes and find the top literally teeming with struggling nymphs. Figs. 5 and 6

[4] For the method of making the egg case, see p. 40.

present the longitudinal section of the egg-case and show one room of each of whole number of suites. Fig. 5 still contains the empty egg-shells left by the emerging insects; in Fig. 6 they are for the most part removed. Figs. 1 and 2 are horizontal sections near the bottom and top (floor and ceiling) respectively. Fig. 1 shows distinctly the arrangement of the cells in cross rows (cf. Fig. 4) which, with their galleries (Fig. 2) meet at the center of the structure in an obtuse angle. Here they are dovetailed together in such a manner as to present a "braided" appearance along the crest of the case, each fold of the braid being a flap, or the trap-door of one of the galleries. Figs. 3 and 4 show horizontal sections of the egg-case through the middle, with and without the egg-shells in the cells. All of the horizontal views show the row of marginal cells surrounding the entire mass, and the heavy partition separating these from the egg-cells proper. These are present in all oötheca but are never used for oviposition. The purpose of these unoccupied marginal cells is not readily understood. We know that the egg-cases are cemented to flat surfaces; this would give ample protection against cold from the bottom. On the top we find the empty galleries which form an air-chamber between the outside covering of the case and the eggs. May it be that this row of unused cells is an adaptation for the lateral protection of the eggs from the cold or perhaps from the attacks of parastic impostors? Of course this is distinctly a southern species, and usually does not live above 40° latitude, and other members of this group are tropical. It is not fully known just how exits are made in the egg-cases of other species; it may be however that this character is a relic from some ancestor which used lateral galleries for exits.

The Emerging Mantis.

In the spring of 1909, after the egg-cases had withstood the natural weather conditions of the winter, 39

were gathered. These gave forth their young at the usual time, at intervals between the 1st and 20th of June.[5] In a previous year's lot, when the eggs were kept indoors, hatching occurred during May, while a few egg-cases which were brought into the living room on December 13, and kept at a temperature of 52° to 78° F., and occasionally moistened, gave forth active nymphs on February 10.

The emerging of the mantis was observed in many cases during three seasons. In every case almost without exception the insects left the oötheca during the early morning. In many instances 6 A. M. found them already emerged, and very seldom did they leave after 8:30 A. M.

Sharp (1895), p. 247, says that the last eggs deposited are the first to hatch. In this species I find that the eggs are deposited just as the egg-case is being made, and consequently the eggs at the broad, rounded end of the case are the first deposited, although the difference in time is very slight indeed. If the last eggs laid are the first to hatch, we should see all the emerging insects come first from the pointed end of the case. As a matter of fact, some egg-cases bring forth all of their young simultaneously and others on two, three or four mornings, but all of my observations lead to the conclusion that in this species the emergence of the nymphs occurs without any regard to the priority of the deposition of the eggs.

One may examine a number of egg-cases at perhaps 6 A. M. and find them apparently "dead as a door-nail;" return in a quarter of an hour and find them teeming with struggling young, all of a honey-yellow color. Struggling young—yes, each one laboring to work its way out of the egg-case and then struggling to free itself from the bag-like membrane which encloses the body and is in turn attached by a silken thread to the bottom of the cell from which the nymph has just emerged.

[5] Riley recorded in 1869 that the eggs hatched in this locality between June 10th and 20th. It is interesting to note that this date persists so exactly after forty-three years.

JUNE, 1909.

Egg case known as	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Total.	Parasites.
A	63			26	1	1																	91	None.
B		27			32	3				5													67	None.
C		20		23	45	7					2												97	15 P. Mantis on June 18.
D				2	44	1		34		4													85	None.
E						92			7			1											100	None.
F						105		3	7			1											116	None.
G								60	13			3											76	None.
H								138		1			1										140	None.
I									109			1											110	None.
J										105		2											107	None.
K										63				2									65	None.
L										85		1											86	None.
M										51													51	None.
N										100													100	4 P. Mantis on June 21.
O										108													108	None.
P										84			1										85	None.
R										33			2						1				36	None.
S										5													5	None.
T													103		2		2						107	None.
U													1										1	None.
V													71				18				3		92	None.
W											92												92	None.
X													98					1					99	None.
Y													3										3	Heavily parasitized.
Z												2											2	Heavily parasitized.
A A														108									108	None.
B B															1	3	3		1				8	Infested by larvae of Anthrenus
C C																	44						44	June 19 & 21. 25 P. Mantis.
D D																	1						1	None.
E E																	94		3	2			99	11 P. Mantis on June 20.
F F																	77				2		79	None.
G G										5													5	None.
H H																							0	None.
J J																							0	None.
K K																							0	None.
L L																							0	None.
M M																							0	None.
N N																							0	Entirely parasitized.
O O																							0	60 P. Mantis on May 25.
	63	47	0	51	122	209	0	235	136	649	94	11	280	2	111	3	239	1	5	2	5	0	2265	

The accompanying table shows the number of insects that hatched each day from each of the 39 egg-cases. It will be seen that in just about one-half of them practically all of the occupants emerged at one time, with only a few stragglers, and that in the remainder the emergence continued through two or three mornings. The mean as well as the mode of emergence falls practically upon June 10.

A number of egg-cases were partially or entirely parasitized by Podagrion mantis. In some cases these parasites emerged before and sometimes after the usual time for the emergence of the host. They do not leave by the openings provided, but bore their own exits in the top and sides of the case. These holes are to be clearly seen in Y, Z, BB and NN in Pl. XV. Not a great deal is known of the life history of this Chalcid. The eggs are deposited in the egg-case in the fall and the adults emerge during the following May and June; just how the parasites spend their life from this time until the following September or October when the oötheca are again deposited and hosts supplied would be an interesting discovery. The fact that they are mature at emergence would lead one to conclude that they should be ready at once for mating and oviposition.

A few were infested by the larvae of *Anthrenus* (sp?). Whether these beetle larvae feed upon the oötheca as well as on the living eggs is not known, but at any event they injure the egg-case sufficiently to destroy the developing embryos.

Four egg-cases, while apparently not parasitized, gave forth only 5, 1, 1 and 5 insects respectively. Five others of apparently similar condition produced no young whatever. I suspected that these latter ones contained infertile eggs, and later in the season discovered that unfertilized females construct normal egg-cases.

Our table shows the greatest number to hatch from any one egg-case to be 140 and the minimum 0 in seven

cases, making an average of 58 for the entire lot. If however we take into account only the twenty-one perfectly good and normal egg-cases we find the minimum 36 and the average 91. These figures are, of course, for the emerging nymphs and not for the eggs. A. A. Girault (1907) opened 20 cases in November and counted the eggs. He found the numbers to range from 49 to 115, with an average of 88. The close agreement of Girault's average of eggs in November and mine for the emerging nymphs in June shows that there must be a remarkably low elimination during this stage, in unparasitized egg-cases.

The eggs and nymphs while in the oötheca are of a yellowish color, excepting that for about a week before the time of emerging the eyes of the embryo are highly pigmented. And at about this time, the distal part of the femur of the hind pair of legs, and a small portion of the head between the eyes, are of a brownish red color. The abdomen is also very slightly so marked. After the insect emerges these markings are conspicuous. Cockerell (1898) who has written upon species of this genus (either *S. carolina or S. limbata*) says that "the eyes are at first sage green, but soon after the emergence of the insect they become blackish." In our species, not alone at emergence are the eys black, but for some time before as well. To be exact, when the egg-cases were opened on May 15, the eye spots, were but slightly pigmented; on May 22, they were very much so, and became more and more intense from day to day. Thus pigmentation of the eyes occurs from about 15 to 30 days, before hatching.

Upon breaking the walls of the egg-case shortly before hatching, one finds the young nymph attached to its cell by a short silken thread. This thread seems to leave the rear end of the body and can be drawn out to a considerable length with a needle. By observing the egg-cases early in the morning on the day of emergence, one

can see the tiny heads pushing their way up out of the "trap-door." By a series of backward and forward movements the insect rises higher and higher out of the cell, until it lies entirely on the top, where it rests quietly for a moment as if preparing for the ordeal of shedding the membranous, sac-like covering which encloses the entire body.[6] As the insect rests one can with the microscope see the two silken threads which seem to leave the cerci, and which soon converge into one heavier thread which apparently leads back to the floor of the cell from which the little nymph has just emerged.

The insects just after leaving the egg-case are shown, enlarged, in Figs. 1 to 5, Pl. XVII. They are still enclosed in the tightly-fitting, membranous sac which is held in position by the silken threads (Fig. 2). After a few moments the thorax begins to enlarge and a lump appears behind the head, which becomes larger and larger until the condition shown in Figs. 1 and 3 is reached. As this lump increases, the head bends further and further downward against the ventral surface (Figs. 4 and 5), causing the prothorax simultaneously to become elongated and rounded until we see the rupture of the tegument; the enlarging of the prothorax seems to push the skin apart causing an opening, and as this organ expands the old skin is pushed further and further back. This bag-like membrane encloses the entire organism, and holds the legs and antennae fast, close to the ventral surface of the body.

This shedding process was long thought by many naturalists to be the first ecdysis, but as neither the antennae nor the legs cast their skin, but the membrane enfolds them as well as the entire body, I do not see how this can hold; neither can this covering be the egg-shell, for we have seen that the egg-shell is left in the egg-case at emerging. In again referring to the casting of this

[6] The hind pair of tarsi protrudes from the sac-like covering, and may have aided the insect in emerging.

membrane immediately after hatching, my observations are entirely in accord with those of Cockerell who, in criticising Sharp, points to the fact that the shedding of this envelope is not a real ecdysis. As I have already shown, this membrane binds the appendages to the body. When this is shed, it merely liberates these organs. Were this a real ecdysis, we should see the skin peel from the legs and antennae separately, as well as from the body.

The skin splits and the prothorax becomes quite large, and in so expanding frees this organ and the head. In examining the old skin we find that part which immediately covers the head to be more heavily chitinized; this "cap" surely protects that organ as the nymph butts its way out of the egg-case.

The animals seem to have enlarged considerably within the few moments, and the head and thorax are entirely free. The skin thus far removed hangs beneath the ventral surface of the prothorax with that heavily chitinized head covering distinctly visible. The antennae are tightly stretched along the ventral surface, terminating somewhere near the anus, reminding one of two tightly stretched telegraph wires. The legs are also visible through the transparent membrane, all nicely folded close against the abdomen.

It is now necessary for the remainder of the covering to be removed, and this is done, strangely enough, by the antennae. I have already shown that the head bends downward and that the two antenna which issue therefrom are tightly stretched along the ventral surface, terminating near the cerci. The head by a series of bendings backward and forward alternately tightens and loosens these cords (antennae). With each backward and tightening motion the skin slips further and further back until the legs are free; these then assist in removing the skin until it slips off over the cerci. The insect is then entirely free and runs away with astonishing

sprightliness, leaving the sac still attached by the short silken thread to the egg-case. The mantis as it leaves the old skin is almost twice the size of the emerging form, even though this entire process occupies but eight to fifteen minutes from the moment the bead-like head pushes through the trap-door to the time when the nymph scampers away from the newly-shed covering. The insects hang to the oötheca by means of the threads for only a very few minutes and not, as Sharp says, "for some days until the first change of skin is affected." When one views the shrivelled little sac left hanging from the egg-cell, one marvels that it really was sufficient to cover the entire insect. The length just at emerging is about 5 mm., and a very few minutes later, after the envelope has been removed, it has increased to about twice this size.

The eggs all develop in their cells with the part which forms the head nearest the exit, so the emerging insect will have little difficulty in pushing its way through. Either the eggs must be deposited right end up along with the making of the case, or the egg-mass in the early stages of its development must turn about in the shell and thus come to a proper position. Gravitation cannot be the controlling agency in this case, because the egg-cases are built at all angles with the direction of the force of gravity. Out of eighty egg-cases observed during two years, I found only one exception to this position of the egg. In this instance, while many tiny heads were appearing all over the crest of the case, from one cell the caudal end of the body and a pair of tarsi appeared. The nymph made a brave struggle to emerge, but after a few minutes it was found dead.

The Moulting Process.

How often the mantis moults is not precisely known. Howard (1901) says it moults at least three times; most

other writers on this species mention nothing about the process. Sharp, in speaking generally of members of the family Mantidae, says that they moult six times. In all of my work with this insect, I have never been able to carry one individual through from the first instar to the last while in confinement. Their rearing is rendered very difficult by the facts that they are entirely carnivorous, attacking only live prey as it moves about, and it seems they also require a variety of diet which cannot be supplied at all times, especially when large numbers are cared for and each insect on account of its cannibalistic habits must be kept in a separate cage. During one season when an attempt was being made to ascertain the exact changes in size and color of these animals, about a hundred of the ordinary household fly-traps were obtained, a mantis placed in each, and the bottom compartment of the trap daily filled with stale beer. This attracted the flies which would eventually find their way to the apartment above which was occupied by the mantis. This arrangement was of course a sort of self-feeder and gave us but little trouble, but the insects never lived long under these conditions. Whether it was the lack of variety of food, or the diet of intoxicated flies that caused their death is not known. Only recently it has been discovered that the mantis nymphs require water, and greedily partake of any offered them on a small brush or sprinkled on plants in the cage. But although it was impossible to carry even one insect through its entire life cycle, enough data were procured to show conclusively that the animals go through at least six moults exclusive of the shedding of the membranous sac just at emerging.

The date of hatching of the insects is from June 1 to 20. The following notes on the time of moulting and the size and color of the insect at that period will help to clear up this problem of the number of moults and the rate of development.

No. 100. June 22, this green insect was taken.[7] After moulting the same day the color was still entirely green; length, 15 mm. July 3, moulted; color, legs green, dorsal thorax and abdomen greenish with light brown patches; length, 19 mm. July 7, entire dorsal surface light brown. July 12, entire insect straw-colored excepting all the legs which were still greenish. July 13, moulted; entire body and forelegs brownish; two pairs of hind legs still green; forelegs not as decided brown as the body, but showed a transition stage between green and brown; length, 22 mm. Aug. 8, moulted; all brown excepting hind legs; length, 28 mm.; died.

Thus we see that this insect showed the following rate of development for the part of its lifetime under observation:

June 22, 2nd moult[8].....15 mm.
July 3, 3rd moult.....19 mm.
July 13, 4th moult.....22 mm.
Aug. 8, 5th moult.....28 mm.

Whether a moult occurred before the length of 15 mm. was attained on June 22, and whether any more would have occurred after Aug. 8 and 28 mm., had the insect lived, must be supplemented from notes on other individuals.

No. 110. June 23, taken; color green; length, 14 mm. July 5, moulted; green with brownish spots on the dorsal surface of first three abdominal segments; length, 21 mm. July 14, moulted; straw-color, with only four hind legs green; length, 25 mm.; died.

So while only two moults could be observed in this insect, they correspond rather nicely in dates and size with those of No. 100.

No. 111. June 23, taken; yellowish green; length, 16 mm. July 1, moulted; yellowish green; length, 18 mm. July 3, no moult observed, but length was 22 mm. July 10, moulted, entirely light brown excepting two pairs of hind legs and coxae of forelegs; length, 25 mm.

No. 108. June 23, taken; entirely green; length, 16 mm. July 1, moulted; all light brown excepting coxae of front legs and all of the four hind legs, which were green; length, 18 mm. July 12, moulted; entirely medium brown excepting legs as described before; length, 25 mm.; died.

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[7] The colors and changes will be again referred to later.

[8] For first moult at 10 and 11 mm., observed on other insects, see p. 16.

No. 130. July 7, taken; entirely green; length, 20 mm. July 12, moulted; still greenish but not a clear color; length, 27 mm.; died July 16.

No. 102. June 23, taken; color, green; length, 12 mm. June 23, moulted; green; length, 14 mm. July 3, moulted; greenish straw color excepting two hind pairs of legs and coxae of forelegs which were still completely green; length, 17 mm.; died.

No. 103. June 23, taken; green; length, 15 mm. June 30, moulted; dark straw color; length, 18 mm.; died July 11.

No. 104. June 23, taken; entirely green; length, 12 mm. June 30, moulted; abdomen yellowish, dorsal prothorax light brown, remainder green; length, 16 mm. July 9, moulted; entirely straw-colored excepting tibia of middle pair of legs, which were still green; length, 20 mm.

No. 109. June 23, taken; green; length, 16 mm. July 3, insect had probably moulted and skin been lost in the leaves; color now dark straw-color; length, 18 mm. July 5, completely straw-colored, with just a faint trace of green on tibia and femur of two hind pairs of legs. July 12, moulted; light brown with heavy black spots on legs; length, 22 mm.; died.

No. 101. June 23, taken; green; length, 12 mm. June 26, moulted; green; length, 15 mm. June 28, part of abdomen yellowish brown. July 3, dorsal and ventral part of abdomen dark brown, dorsal surface of thorax gradually changing to brown; head, all the legs and the ventral surface of thorax still grass green. July 9, moulted; entirely brown excepting the greater part of each of the four hind legs and coxae of forelegs; length, 18 mm. July 22, moulted; color same as before; length, 22 mm.

These notes made during 1911 support with only very slight variations the phenomena noted above, pointing to the conclusion that four moults occurred between June 22 and Aug. 8. From the table below it is evident that another moult (the first) occures previous to that time, when the insect is 11 to 14 days old.[9]

Hatched.	Moulted.	Length.	Color.
June 11	June 22	10 mm.	Yellowish
June 7	June 21		Dark brown
June 7	June 21	11 mm.	Greenish
June 11	June 24		
June 11	June 24		
June 11	June 24	10 mm.	Head, thorax and appendages light green; abdomen blackish
June 11	June 21	11 mm.	Light green
June 11	June 24	10 mm.	Green with black spot on prothorax where legs join

[9] From notes made in 1910.

This, with the four moults previously described, gives us five moults. At this fifth moult the wing pads are highly developed, and the insect measures from 28 to 32 mm. in length; it is now in the instar immediately preceding adulthood, when one more moult completes the process of development, and the insect attains a size of 48 to 60 mm.[10]

It is hardly possible that a moult could have escaped observation. Hence we may feel confident in concluding that there are at least six months and seven instars in the life cycle of our mantis.

Pagenstrecker (quoted by Packard, Text-Book Ent., p. 616), finds that the Mantis religiosa moults seven times, having eight stages in its development, including "that before the amnion is cast." Hence we arrive at the same conclusion, for in our species we have six ecdyses and seven instars exclusive of the shedding of the envelope just after emerging, which, as we have seen, can hardly be regarded a true moult.

Of course when circumstances are such that individuals cannot live to maturity in confinement, and since sex cannot be distinguished until late in the insect's life cycle, it has not been determined finally whether males and females pass through the same number of moults in their development. It may be possible however that the conditions of confinement, food, temperature, etc., may influence the size of the insect and the time of moulting, but it seems hardly probable that it could cause a variation in the regular, established number of moults.

It is extremely difficult to handle a delicate and perversely active little nymph which insists upon rearing up the abdomen in a semicircle while he is being measured. The measurements from life were all made under these difficulties, and may err slightly either way.

[10] This measurement is for adults that were not confined in the earlier stages.

In 1910 the first adult female appeared on Aug. 16. In 1909 the first gray female came to maturity on Aug. 3 and the first green one Aug. 9. All these were taken in the open, where development would probably be a little more rapid than in confinement.

The nymphs of the two sexes are very similar and cannot be distinguished by appearance until the instar just preceding adulthood. In the adults, the difference in the size and shape of the bodies is so great that they might easily be mistaken for two distinct species. The male has a long, slender body completely covered by the wings; the body of the female is much broader and the wings are aborted so that they cover only a part of the body.

Method of Shedding the Skin.

The method of moulting is the simple one characteristic of most Orthoptera. The skin splits along the prothorax and the insect works its way out; usually the head and prothorax are pushed through the opening first, and the abdomen and legs are freed later. Frequently the smaller nymphs hang with the hind pair of tarsi interlocked around a twig while undergoing this metamorphosis.

In Pl. XVIII, Fig. 2 we see a twelve-day insect (¾ natural size and enlarged) undergoing its first real ecdysis. The body is wholly free and the insect is struggling to extricate its legs from the old skin. Pls. XI, XII, XIII show the nymphs after the fourth moult, when the wing-pads are first apparent.

The mantis all hatch at about the same time and, when the insects are free in nature, the whole population seems to moult at about the same perid, so the rate of development of all the individuals is kept about parallel. In other words, when one finds mantis, say in June or September, they are almost always all very much alike in size and form. Hence we do not find, as Rathvon (1862) records, that the "mothers often feed upon their

own young," for the parents have all died the year before, nor do the adults ever get a chance to feed upon nymphs, for the time is short when the instars overlap. Thus we seldom find the insects in more than two stages at the same time.

Food Habits.

The mantis is entirely carnivorous. In this respect it differs radically from the other members of the family Orthoptera. It will attack only insects in motion. The very small nymphs in confinement were fed upon plant-lice, while the larger ones were fed flies, grasshopper nymphs, small crickets, etc., although where many mantis were caged together their principal diet seemed to be one another. The nymphs are cannibalistic, and in the adults, the females alone seem so. I have seen them devour one another as well as eat the males, but never yet have I seen an adult male attack either a female or another of its own sex. Whether the male nymphs are cannibalistic could never be ascertained with absolute certainty because the sexes are indistinguishable in the earlier stages.

The mantis have been observed to feed upon the following organisms:

> Nymphs of cockroaches; (*Blatta orientalis*) the white ones four days old were highly relished. Nymphs and adults of the German roach *Blattella Germanica*. Colorado potato bugs, discarding hard parts. Larvae and adults of *Grapta interrogationis* Fab. Hairy caterpillars and others. The common tomato-worm (larva of the Sphinx-moth). Aphids. Male adults of the Bag-worm (Lepidoptera). Ants. Adults of the May-fly (Ephemeridae). Honey-bees. House-flies. The cucumber beetles *Diabrotica* 12-*punctata* and *Diabrotica vittata* were greedily devoured. Blister Beetles, *Epicauta pennsylvanica* (De G). Pennsylvania soldier beetle, *Chauliognathus pennsylvanicus* De Greer. Also *Chauliognathus*

marginatus Fab. Lace-wing adults, *Chrysopa* Sp. Crickets. Cabbage butterflies, *Pieris rapae.* Nymphs of grasshoppers and locusts. Frog, about one-half inch in length, was held in the forceps and kept in motion before the mantis. The frog was seized and about one-fourth devoured.

Many kinds of food insects were offered to the mantis upon forceps. Potato-bugs were refused when the insect was not terribly hungry; robber-flies (Diptera) and stink-bugs (Hemiptera) and very large grasshoppers were always rejected. The insect never hesitated to jump at the forceps bearing palatable bits, and never delayed to back away when a distasteful morsel was offered. From this I would infer that the sense of smell or of sight, or both, must be highly developed.

A bag-worm larva removed from the cocoon was offered to a number of mantis, but in every case but one it was refused. In this case the mantis at first ran away very fast from the forceps carrying the larva, but stopped and turned its head around, and when I insisted again it grasped the "bug," put it to its mouth and immediately dropped it to the floor in apparent disgust.

One mantis was observed making an attempt to grasp a wasp (*Polistes Sp.*), but after eyeing it for a few seconds the mantis jumped away. I followed with the Polistes in the forceps, but it would dodge from one side to the other when the wasp was thrust directly in front of its mouth. In a later experiment, a mantis ate the head and part of the abdomen of a male wasp (*Polistes Sp.*).

A mantis attempted to devour a white moth (family Arctiidae) by biting into it at the thorax near the basal part of the left wing. After the wing had been severed the insect continued its efforts to penetrate the hard chitin. Making no headway it left the insect clinging to the wire screening. After about five minutes it returned and again began to bite away at it at the same

spot; after two minutes persistent effort it became disgusted and dropped the moth to the floor. Taking it in my forceps I again offered it to her repeatedly, but she persistently refused. This mantis must have been pretty hungry, but still had not the "ability," "wisdom" or "foresight" to know that by trying at a point further down, the soft parts of the abdomen would be found. My second insect made a like refusal, but in a third experiment the mantis began by devouring the caudal end of the moth, eating headward, and in fifteen minutes it had consumed the entire insect. Of course it was probably wholly accidental that the last mantis found the soft parts first.

A small nymph, aged 17 days, was seen to feed upon two small Hymenoptera one morning. At 6:30 it pounced upon one, and holding it fast in the forelegs began to devour it. After two and a half minutes, whatever remained was held in the mouth while the second was seized; this was held tightly while the first was being devoured,—and this without any help from the forelegs in holding the first. This was entirely eaten in five minutes, immediately after which, the second was consumed in eight minutes. Perhaps the first was eaten hastily to prevent the possible escape of the second.

A marked mantis, whose entire prothorax was thickly covered with green paint, was devoured, paint and all, by a comrade, and so far as I could see agreed perfectly well with the insect.

The adults have the most human characteristic of breaking large prey in two parts, one "hand" holding one portion to the mouth while the other tightly holds the second course in readiness.

While the nymphs are greedy eaters, I believe that the adults, at least the older ones, can get along for a considerable time without food. At one period of three days early in September when food was very difficult to obtain, out of 28 caged specimens which had no food, only

5 died; hence we have no reason to conclude that even these died from this particular cause. The adult males require little food, and in confinement seem to live as long as the females.

The males do not eat while in copulo, since their forelegs are used for clinging. The females, however, having these appendages free, lose no opportunity to grasp a choice morsel.

Again referring to the cannibalism of the mantis, Pl. VII shows a gray and a green female in combat to the death. The spiny forelegs of each are locked about the thorax of the other, and the head of the fair one (green) is about to sever.

Enemies of the Mantis.

Small red ants were once accidentally introduced into the cages along with the aphis. Instead of the carnivorous nymphs eating these also, the ants although much smaller, immediately fell upon them, first severing the legs at the joints and then dismembering the other parts of the body, while the struggling mantis tried to get away. It was at first thought that the ants behaved thus in order to protect their dairy, but it was later discovered that they carried away all the parts of the dead mantis, evidently cherished as palatable bits. The mantis when older, however, reversed the attack and greedily devoured the ants.

Another grave enemy to the eggs is the Podagrion mantis already referred to, and in all probability the larvae of Anthrenus sp. also. A spider was once seen devouring a mantis nymph. What part birds play in keeping their numbers in check is unknown, but both sexes, dead or alive, were greedily eaten by poultry, and even the egg-cases, both old and new, were likewise devoured.

Upon one occasion when I was testing the ability of the mantis to capture and kill honey-bees, one was tied

near the bee-hive entrance by a silk thread around the prothorax. The mantis received two severe stings on the side of the abdomen where the chitin is very thin. The animal bent the body around in a circle and bit frantically around the wounds, perhaps injecting saliva —I could not discern. An hour later each wound was covered by a drop of fluid and that side of the abdomen was much swollen. The insect survived, however, and soon behaved quite normally, mating three days later.

It was noticed that the mortality was unusually great at two or three days after emergence. Food was plentiful, and cannibalistic habits were not carried on to a great extent. It was discovered by the aid of the microscope that the insects at the time of emerging, as well as the egg-cases, were teeming with mites,[11] which in all probability caused their death.

Color.

We know that all mantis at hatching are of a light yellowish color, the eyes alone being pigmented. Within a few hours this color becomes darker. The color of the immature insects at any stage after the first moult is not constant, but varies from a grass green to a dark, mottled gray, almost black, and including a vast variety of dull yellows and browns. It frequently occurs that a single individual will exhibit many or all of these colors in varying combinations.

In the adult females we find the same conditions in the coloration of the body. In addition the wings are green, yellow or one of a variety of shades of gray, or mottled. Sometimes we find a brown adult female with green wings and sometimes a green one with brown wings. The males do not exhibit such a marked variety of color, but are usually extremely dark and the wings mottled, although a good many of them have green legs, and occasionally one occurs with green body, head and

[11] Identified by Dr. H. E. Ewing as *Pediculodes ventricosus* Newport.

appendages, but never yet has a male been found with green wings. In some of the males the wings are hyaline, but observation has shown that this condition usually exists for a short time after moulting and before the pigment is distributed. In many the two pairs of hind legs seem to acquire the darker color before the front ones do; many are seen with the hind legs dark gray while the front pair are still green. These are always in contact with the material upon which the insect rests, the dull, dark bark of trees, etc., while the front ones are held high in the air.

Near to the center of the wing is a highly pigmented and clearly defined spot which is very conspicuous in the green winged insects, but not so much so in the dark ones. The utility of these is not at once apparent, although one is likely to suspect at first thought that they are to give an aggressive appearance when the female raises her wings in the attitude of fight. When the insect is at rest, one wing partly overlaps the other sometimes covering this pigmented spot.

Little is precisely known concerning the regulation of colors in this insect, but it has hitherto been generally thought that the males were brown and the females green (Howard). Riley (1869, p. 170) says: "The green form is almost entirely confined to the female sex and seems to be the most common color of this sex when full grown." According to Scudder (1896) this dimorphic female was for a time specifically divided, the gray one being called dimidiata and the green one carolina. But in criticism of this he says that since the two forms occur in the United States he cannot see how they could be specifically separated, since there is no similar distinction in the male, which is never entirely green.

My own observations have fully satisfied me that the adult females appear not only in the green form (Pl. I) and in the gray (Pl. V)[12] but also in every gradation

[12] See also Plates VI and VIII.

and combination of these colors between these forms illustrated, and that these variations can be found in every stage of the insect's life cycle after the first moult. As already stated, the color of the male does not vary so greatly, but still green-bodied insects are found.

The color of the mantis certainly serves to protect it, even though the green insects are not always on green leaves, nor the dark ones on dull bark. The photographs nicely show how, when resting on foliage, their color seems protective, and their appendages blend well with the twigs. In spite of the fact that, so far as I can see, no discrimination is shown in the selection of their background, the insects blend beautifully with their surroundings; their form as well as their color seems to make them inconspicuous amid the lights and shadows of the foliage. Thereby they are protected from the attack of enemies and aided in successfully stalking their prey. Of course that does not necessarily mean that their coloration came about on that account. Perhaps this phenomenon can best be explained by Beddard, who says: "It is often not easy to find a sixpenny piece, which has been dropped on the carpet, but the reason for this is, not that the coin is protectively colored, but that any small object no matter how colored is difficult to discover amid a variagated environment."

In fact the younger nymphs, with their wings not yet developed, were harder to find than the adults. Usually when insects were needed, sweeping the shrubbery with a net had to be resorted to, although both nymphs and adults were not infrequently to be found stretched across some bright flower waiting for insects, and were extremely conspicuous, but on such plants as the tamerack, iris, hops and canna, the green ones were always inconspicuous. Blending so nicely with their environment may be instrumental in securing their prey, but to what extent this protects them from birds, toads and other enemies is not known, although Di Cesnola's experiments

upon the European species point to the conclusion that it does afford protection.

One wonders about the value of protective coloration when one sees a dark gray female, resting on a green tamarack, very conspicuous indeed, greedily devouring one which is green. But again in contrast to this, when the green nymphs are at rest on the clematis or hop vines and an attempt at their capture is made, they dart from leaf to leaf, quickly turning to the under side, then drop to another and vanish in less time than it takes to tell.

Color Change.

We have seen in the chapter on the moulting process that the insects at hatching are all alike of a light yellow color. Just after the first real ecdysis they occur in many colors, the two extremes being distinct green and dark brown. We have seen that green insects gradually change to brown;[13] this may be due to the color of the environment. My attention was first attracted to this by the following observations upon nymphs and adult females which were kept for other notes.

In the first instance the cage contained no potted grass nor green things of any kind, and the insects could rest upon nothing but the almost black wire screening of the cage. It seemed to me that the ventral surface of this adult female—the part in constant contact with the screening—became darker from day to day. Whether this happened on account of the environment or in mere coincidence is not known, but we must not fail to consider that this was a full-grown, winged insect when placed here.

In the second case the adult insect when placed in the cage was entirely green, both body and wing. After being there for thirty-four days until its death, we found the wings and the abdomen under the wings still green,

[13] See pages 15, 16.

shading into brown at the exposed parts, while the ventral and lateral parts, as well as legs, head and thorax,—in fact all constantly exposed parts—were dark brown.

On another occasion several green females in the next to the last instar were placed in a breeding cage together with several pots of growing grass which would serve as a background and foothold for both the mantis and their prey. During a heavy shower the cages were taken into an outbuilding, and fortunately or unfortunately they were forgotten there for about a week. During this time the grass died and turned straw. When they were discovered the mantis had devoured one another, but the two survivors which were found with difficulty had become adult, and there they were—body, legs, wings and all just the right shade of straw color.

This led to other work with the insects. The difficulty of maintaining in one's own home a large number of animals which are cannibalistic, voracious and carnivorous, and which require a variety of living food can perhaps be imagined.

In an experimental way I tried to find just how and why the colors changed and if environmental conditions were the sole causal factor. For three years the work was carried on with not at all encouraging results. The first year lamp-chimney breeders were used. The mortality was great owing to the difficulty in the regulation of moisture and temperature. The second year a number of home-made wire cages were used and a large number of individuals placed in each. The extreme cannibalistic tendencies reduced the numbers to almost nothing, but the work still gave a clue to what were the tendencies of the adaptation of the animal to its environment. Later about a hundred fly-traps were procured and set up as described elsewhere in these pages.

The work will probably be carried on for another season, but enough data have been gathered that we can

confidently state in a preliminary way at least these conclusions:

1. The green nymphs are capable of changing to dark gray or brown when the environment is dark.

2. The green insects will in all probability remain green when the environment is favorable to that color.

3. When once the gray color is acquired it is permanent despite any environmental conditions.

Poulton[14] says that "all green colouration without exception is due to chlorophyll, while nearly all yellows are due to xanthophyll." Tower in his work on Colors and Color Patterns in Coleoptera goes more into detail on the coloration of Orthoptera. He says that in the Orthoptera the prevailing colors are blacks, browns, greens, yellows and rarely reds; the browns, blacks and some of the yellows are cuticular colors; the reds and most of the yellows are hypodermal. The Orthopteran forms are largely vegetable feeders and "the greens and yellows are centainly in part derived from plant pigments." Thus the two color authorities reach the same conclusion, that the greens and yellows are derived from plant pigments. But here a mantis, an Orthopteran form which never in its life eats anything but animal food, attains precisely those colors. It is true that this insect, while entirely carnivorous, might acquire a certain amount of chlorophyll by feeding upon insects which in turn are phytophagous (caterpillars, aphis, etc.) and thus develop the green color, but in that event why should this effect follow in only a part of the insects when all of them live upon practically the same food supply?

To assume that the coloration of the mantis is a vestige from the time when their ancestors were vegetable feeders is far from satisfying.

[14] Quoted by Vernon, Variation in Animals and Plants, p. 291.

Mating Habits.

The very fact that the female mantis almost always devours her mate while the pair are in copulo, and the male unresistingly clings while he is slowly being eaten, makes the mating habits of this species arouse more than ordinary interest.

Pl. II is a very good photograph of a pair in the characteristic position of mating. The female here illustrated is green, while the male is an ordinary dark insect. The illustration nicely shows the general structural dimorphism of the sexes, as well as the comparative size of the antennae.

That the males seek the females I have not a doubt, for in many cases they were found clinging to the outside of the cages containing the latter. The insects display so much individuality in their mating habits that it will be well to give the details of the behavior of a few typical individuals during this period.

Experiment 1. Aug. 14, 8:00 A. M., a male and a newly-matured female were placed in a large breeding-cage. A half-hour later the female was walking about the ceiling of the cage, gracefully mounted by the male (but not in actual copulo), who tightly clutched her around the prothorax with his forelegs. The female was greedily devouring hairy caterpillars. The entire day was spent in slowly walking thus about the ceiling. Actual mating occurred at twilight, after a courtship of about ten hours, during all of which time the male seemed in quite the proper position. They separated some time between midnight and 6 the next morning, but at 10:30 the male had again mounted, and at 12 o'clock noon they resumed copulation and continued throughout the afternoon, severing some time between 7:30 and 10 that evening. Again the next morning, Aug. 16, at 6, the male had mounted for the third time, but actual mating did

not take place until the afterooon of the day following, and they severed early in the evening. Aug. 18 and 19 they were observed frequently, but no activities occurred during these two days; it was not until noon, Aug. 20, that the pair again mated.

Aug. 21, 7:00 A. M., the pair found separated; 2 P. M., male mounted on female; an additional male introduced.

Aug. 22, 7 A. M., all found separated; 7:30, one of the males had mounted. Aug. 23, 6 A. M., all separated. Aug. 24, one male mounted. Aug. 25, 6:30 A. M., female again in copulo with one of the males; 4 P. M., severed, but retaining position of mounting. Aug. 26, 6:30 A. M., this pair had resumed mating; 3 P. M., severed. Aug. 27, 7 A. M., found first egg-case which had been deposited during the night.

Thus this female mated six different times and remained so about forty-five hours and deposited one egg-case during the first 14 days of its adult life.

The pair remained separated all day (Aug. 27) until 9:30 P. M., when they were again found in copulo, after a lapse of less than twenty-four hours since the deposition of the egg-case. No observations could be made the next day, but on Aug. 29, 6 P. M., this female was again mounted by one of the males, which condition continued until the evening of Aug. 31. Thus for three days she carried him without actual mating. Why this conduct unless another egg-case was soon to be deposited? Was the male inefficient, and if so, why was he not devoured? Was the female still exhausted from egg-laying five days before? At this time this male was removed and another which appeared to be as yet unmated was placed in the cage. Only five hours later, this pair was found to be in actual copulo; this indicates that probably the other male was exhausted. During the following forenoon, Sept. 1, they separated. On Sept. 2, 6 A. M., the lifeless remains of the male were found, with the abdomen entirely eaten away. Why did the female carry

the useless mate for three days without molesting him, and then turn around and attack one which might yet have been of some use?

The female was left alone until Sept. 4, when a new male was introduced. The next day he was found dead, with no signs of having been attacked by the female. On Sept. 6 still another was introduced, but no observations could be made until Sept. 10, when no male was found; evidently he also had been devoured.

The female was left alone and unobserved until Sept. 13, when the second egg-case was found to have been very recently deposited. The next day she was dead.

We learn from this experiment that the female mates many times with one or more males, that two egg-cases may be deposited, and that the duration of adult life was, in this case, 34 days.

Experiment 2. Aug. 14. The cage contained two adult females and one in the instar just preceding adulthood. A male was found silently resting on the outside of the cage; he was grasped by the long prothorax and gently ushered inside. But his welcome was not a gracious one, for the next morning he, as well as the nymph, had been eaten. Another male was placed with the two remaining females on the afternoon of the 16th. Early the next morning he was found in mating with the gray female; they separated from about noon until 3 o'clock, when they resumed mating until some time in the night. The next day, Aug. 18, the male turned his attentions to the green female, mating with her in the afternoon. The following day all were going about singly until 5 P. M., when the gray female mated for the third time. This gray one mated again on the afternoon of Aug. 21, and the green one for the second time on Aug. 22. On the 24th the green female carried the male for some time but actual copulation did not take place until the 28th. At this time the gray was the successful rival, and she concluded this her fifth mating, with devouring her mate.

None other could be found to succeed him. On the morning of the 30th, two new egg-cases were found. It seems probable, though uncertain, that each female had deposited one, for further observations proved that usually an interval, with copulation, occurs between the making of the first and second egg-case.

On Sept. 1 another male was secured and placed with them. No observations could be made until the evening of the 3d, by which time he had been eaten. On the next morning the green female was also dead, but the death had been a natural one as no marks of violence could be found on the body. From this time forth no males whatever could be secured, and the gray female alone remained. Ten days later a newly-made egg-case was discovered. This female was not observed in copulo between the first and second egg-laying, although this may have occurred during my absence from the experiments during the first of September. This new oötheca was placed flush with one of the first ones, slightly overlapping it, as if intended for its continuation. Did the insect recognize its first effort and attempt to enlarge upon it, or was the choice of location purely accidental?

This insect was observed daily until its death Oct. 8, and fed occasionally, but it required less food from day to day as old age came on. After the chilly nights she would be found stretched upon the wires of the cage quite as if dead, but with the warm rays of sunshine she would soon revive.

Experiment 3. Aug. 13. A male and a gray female were caught in the garden and placed in a cage. Soon the female was observed to be carrying the male, and so they walked about during the entire day, the female for diversion devouring many flies; not until sunset did actual copulation take place. This mating continued for an unusually long time, until between midnight and morning of Aug. 15, or more than eighteen hours. They mated again on the 17th, from early morning until late

afternoon, and from the middle of the afternoon until night of the 18th, and after that appeared quite indifferent to each other until the afternoon of the 21st, when they again remated for a few hours. They went about singly for the next three days, after which the male mounted for a few hours in the evening, but did not accomplish mating. By morning he had been dislodged, but in the afternoon he again persistently remounted. He was carried thus by the female all day, and it may be all night too. The next morning revealed an interesting double surprise; there was an unfinished egg-case made during the night, and the pair was again in copulo. Whether she made this oötheca with the male on her back, or whether he left her while she hurriedly constructed it and then insistently returned, is not known. The nest certainly offered the appearance of hasty or interrupted work, for it measured only 10 mm. in length and was not finished with the usual nicety of a gradual slope from the top to the base, but it had the appearance of having terminated abruptly. The oncoming of oviposition probably prevented copulation, for we know that the male was mounted and in readiness for the three days preceding, and that it occurred within a few minutes or at least a few hours after the egg-case had left her body.

They continued in copulo throughout the day, but were separated all of the next. On the morning of the 28th, it was found that an additional oötheca 22 mm. in length had been joined to the first one, during the night. We shall not venture to call this more than mere chance or coincidence, and yet this was the second instance of a mother mantis placing her second nest in close juxtaposition to the first, quite as though it were a continuation of it.

For the next two days each went about its own affairs, and on the morning of the 30th the male was gone, evidently having been devoured since escape was impos-

sible. From this time on the female was alone. On the morning of Sept. 10 she was found dead, but during the night before she died she had built another egg-case, a beautiful piece of work 30 mm. long. Shall we say that this female deposited three oötheca? Hardly, since the first installment was abnormal and either interrupted or made under difficulties and the second part soon added to it, and both parts together compared well in size with the second.

Experiment 4. Aug. 15. The pair mated almost immediately after being placed together in the cage at 7 A. M. At noon however they separated, probably on account of a heavy shower in which they were caught. During the next few days, ordinary uneventful matings occurred at the following times: from early morning until noon of Aug. 16, and from 9:10 P. M. of that same day until noon of the 18th; from early morning until noon of the 21st, and about the same hours on the 23rd. On the 24th, the male again mounted, but the female would not consent to actual mating, and the next morning she was found pleasantly devouring him. A new mate was at once supplied; at 4 P. M. he also mounted her, but again copulation did not occur. The next morning revealed that he likewise had been eaten and an egg-case had been made during the night. No new mate could be supplied until the evening of the 27th, and he very soon mounted. This time she carried him, without attack or resistance, for about eighteen hours before actual copulation occurred. In this respect the attitude of the female seemed very different after oviposition from just before. This copulation continued until some time in the forenoon of the 29th, when the male severed but did not dismount. He retained this position, without resuming mating, for almost three days, when at 4 P. M. on Aug. 31 he dismounted without any display on the part of either individual. This male was now removed and a new one introduced which mated with this

willful female in less than two hours. This continued until the forenoon of the next day, Sept. 1, and at 6 that evening she ate him. A new one was thrust in with her immediately, and before 9:30 she had accepted him as a mate. By the next morning they had separated. Copulation was repeated that night, Sept. 2, and again all day on the 4th. After this each went its own way, until the morning of the 7th revealed an explanation for this conduct during the past three days in the form of a newly-made egg-case. After this, copulation was promptly resumed early the next morning, but by 8:30 A. M. the male, already headless, was being slowly and calmly devoured by his mate, while he clung, apparently automatically, without the least effort of resistance. At 2 P. M. the leisure meal was still in progress and by 4 o'clock the entire body, excepting a wing, had been eaten. No other mates could be gotten, so henceforth her life was spent alone in the cage, until her natural death Oct. 10. During her entire life after her capture, 56 days in all, she took very little food, excepting occasionally a mate, and for the eight days preceding her death she ate nothing whatever.

Experiment 5. Aug. 15. A male and two females, a gray and a green, were placed in a cage. Mating soon took place with the green one. At 6 the next morning they had severed, but they reunited at noon and continued so until some time during the night. At 3:30 P. M. of the following day, Aug. 18, this male turned his attentions to the gray female. Mating continued throughout the evening, but early the next morning only her gray wings were to be found on the floor of the cage; evidently she had been devoured by her rival, for the adult males never attack members of either sex. The remaining pair were indifferent to each other, so on Aug. 20 a new gray female was introduced. The next morning however the male was found to have returned to his old green mate, but at 2 P. M. they separated. No activities whatever took place until the 23d, when the green female

was found to be again in mating, but the male was headless. The pair was chloroformed thus for a photograph (Pl. III), so further notes could not be made upon this experiment.

Experiment 6. Aug. 18, 7 A. M. A pair in coitu were found in the garden and gently placed in a cage. At 10 o'clock they had severed, but resumed mating at 3:30. At this time a gray female was introduced, and by 7 P. M. the male had left the green female for her. The next morning the male had severed but not dismounted; she carried him all day until 5 P. M. when copulation was again resumed. The next day he was only being carried again; he persisted in this position until midday of Aug. 21, when he was devoured. By the following morning the green female had also been devoured by her voracious companion. A new male was at this time placed in the cage with the remaining gray female, but no mating occurred during this or the three days following, and on the 26th he likewise fell her victim. But the next morning revealed an egg-case made during the night. The female was now left alone until a new mate could be gotten Sept. 1; copulation was begun promptly that evening and continued throughout all the next day. They separated for a few hours on the 3rd, but reunited that evening. On the 4th he was rejected, and on the 5th he was eaten; none could be found to take his place. On Sept. 10 the second egg-case was found. The insect lived an uneventful existence henceforth until its demise on Oct. 6.

Experiment 7. Aug. 18. The pair mated from noon until 3:30, and from 5 P. M. of Aug. 19 until noon of the 20th, and still a third time on the 21st, from 3 o'clock until night. For the four whole days following the pair was closely observed, but mating did not occur. On the morning of the 25th an egg-case was found, which evidently had been finished only a few hours previously. At 4 P. M. the male was devoured by the female. A new

one was promptly introduced but no mating occurred; the next evening he was found dead, but the death apparently had been a natural one. Aug. 27, 7 A. M. another was introduced, but he too was immediately devoured; his successor promptly met with the same fate at 4 P. M.—the third victim of this female's voracity. No more males could be secured until Sept. 1, when at 4 P. M. one was introduced only to be devoured in less than two hours. Two more were promptly added; by 9:30 one of these had mounted the female, but actual copulation had not begun. This condition continued until midnight of the 2nd, but at 6 the next morning the male was found dead. Twenty-four hours later a large, newly-made egg-case, the second for this female, was found and already she was again carrying the male, but without mating. This performance continued all day of the 4th and 5th, but the next morning revealed that this male also had been devoured. No more mates could be supplied, so the female lived alone until her death Sept. 10.

In addition to the foregoing complete experiments, the following fragmentary observations will contribute to our knowledge of this subject.

A male going through its last moult and becoming adult on Aug. 22, mated in the evening of the following day at the age of about thirty hours.

On one occasion an old male and three females were taken at random and placed in a cage. None of the females paid any attention whatever to him, so after six hours he was removed and an active young male which had voluntarily come to the cage was placed inside. In a short time one of the females mated with this one, while the other two assumed a furious attitude, erected their heads, curled their abdomens, raised their wings and occasionally leaped angrily at the pair. The couple was soon isolated to prevent any calamity. It is interesting that these three females all disregarded the first

male, and that immediately afterward all were extremely anxious, as their behavior clearly showed, to win favor of the second.

On Aug. 23, two males taken at random were placed with a gray female. They both fought for her possession; after half an hour one of them retired and the victor mated with her. Copulation continued until 5:30 the next morning. Within a half hour the pair had severed, and already both males were clinging to the female, one on each side, tightly clasping her prothorax with their spiny legs. Thus they persisted and contended until 4 P. M. when she fell from their grasp—dead—a victim of too ardent wooing.

On another similar occasion when a female was placed with five males, four of these were simultaneously clinging to her at the same time, the whole affair forming one struggling mass of life. Throughout even this she succeeded in maintaining her position, clinging to a twig.

A copulating pair fell from the ceiling of the laboratory upon the back of my neck. I brushed them hastily to the floor, and this caused their separation. The female ran swiftly away, pursued by the male, but even with the advantage of two feet of distance she was overtaken, mounted and in copulo in less time than it takes to tell.

On three occasions when two males were placed in one cage, they mounted one another, and spent from 3 to 6 hours in the normal attitude of mating, although no attempt was made to actually copulate.

In the accompanying photograph (Pl. IV) we have an attempt to show many individuals displaying various characteristic activities of the animal, in one group. In the background one can indistinctly see a pair in copulo; a gray female in the characteristic attitude of fight, the wings raised in a quarter circle like those of an angry goose, rests on the top of the twig, and a green female

is just beneath. In the lower part of the picture, a male can be seen about to mount the female. Note the greatly distended abdomen of the female which very soon will oviposit.

Pl. III shows two pairs which were chloroformed during mating while the male was being devoured from the head backward, as usual. This shows both the left and the right view of the connection.

The practice of the female devouring her mate may be one of the little economical devices of Nature. Since the male had already mated—done his duty, as it were—why continue a useless life? Why should he not go to help nourish the female while she goes through the function of egg-laying?

A female became adult on Aug. 16, was isolated and on Sept. 9 deposited an egg-case, but died three days later. Another which became adult on the same day and was likewise kept virgin, oviposited on Sept. 4 and died six days later. Both egg-cases appeared in all respects normal, but of course nothing emerged from them the next summer. This shows that females are capable of ovipositing and building the complex nest from their own bodies without the stimulus of fertilization, when about twenty days old.

It was thought that the males probably find the females by means of scent or other sense organs located in the antennae, as we have found in the cecropia moth,[15] but experiments on the removal of the antennae proved conclusively that this is not the case in the mantis.

Males with one or both antennae amputated, mounted and mated with the females just as quickly as did those with these organs intact.

It was also thought that the cerci of the female performed some function in mating, but the removal of these organs showed that they were of no value, for

[15] Trans. Acad. Sci. of St. Louis, 20: pp. 275-308.

matings occurred just as readily in the cerciless females as in the normal ones.

To briefly summarize, then, the points to be gleaned from these observations:

The males as well as the females are ready for mating very soon after becoming mature, *i. e.*, very soon after the last moult.

The species is highly polygamous and polyandrous and spend much time in mating. About six or eight hours is the usual duration of a single coitus, but it may be much less, or it may be extended to fifteen or eighteen hours.

As a rule, two egg-cases are deposited by each female, but mating is usually repeated in the few days' interval between the two.

The female generally refuses to mate during about three days preceding oviposition, and is at this time especially likely to rid herself of annoying suitors by eating them.

The male seeks out the female and will contend for her possession, the female will also fight for the male but no coquettish display or other antics of courtship such as have been recorded for other animals and insects, have been observed in either sex of this species.

The Making of the Egg-Case.

The making of the egg-case in the mantis is truly a wonderful phenomenon,—all the more so when compared with the process in other members of the family.

The eggs of most of the Orthoptera are deposited in capsules which may contain one or a great number of eggs.

In the cockroaches (Blattidae; see Sharp, 1895, p. 229 et. seq.) the eggs are laid in a horny capsule formed within the mother's body. This is carried about, protruding from the hinder part of the body, until it may be deposited in some suitable situation.

The eggs of the walking-stick (Phasmidae) are not systematically deposited but are discharged at random, remaining wherever they may chance to fall. The eggs resemble seeds and are dropped singly, each one enveloped in a capsule which is provided with a lid which is pushed off by the emerging insect.

In the locusts (Acrididae) we see the mode of oviposition differing widely from that of both the cockroach and the walking-stick. With her hard gonapophyses she excavates a hole in the ground wherein she deposits her eggs, together with a quantity of fluid. This hardens and protects the eggs, and hence in function corresponds to some of the capsules made by other insects of this group. It may have been from this primitive way of protecting the eggs that the present complex way of egg-case-making in our mantis evolved.

Some of the true locusts (Locustidae), katy-dids, etc., deposit their ova in twigs or stems of plants, arranging them in a very neat and compact manner, while others deposit their eggs in the earth.

The cricket (Gryllidae), which has a subterranean existence, deposits from two hundred to four hundred eggs. The mother watches over them very carefully until they hatch after three or four weeks; she then supplies the young with food until their first moult, after which they disperse.

For a good many years it was quite unknown just how our species makes its egg-case. It was thought by some naturalists that the eggs were deposited and the whole mass then covered by a substance which hardened over them, the whole process resembling the oviposition of the grasshopper. Others thought that the whole mass was formed inside the body of the mother mantis and then expelled entire, similar to the method of the Blattidae.

Sharp (loc. cit., p. 246) says: "The eggs of Mantidae are deposited in a very singular manner. The female

emits some foam like matter in which the eggs are contained. This substance dries and forms the oötheca; whilst attaining a sufficient consistency, it is maintained in position by the extremity of the body and the tips of the elytra, and it is shaped and fashioned by these parts."

One would take it from the above quotation that this account of egg-laying is for the entire family. If it be meant as Sharp states, an exception occurs in Stagmomantis carolina. Here the egg-case is fashioned only by the organs at the extremity of the body, and not in connection with the tips of the elytra; neither do the elytra or the tip of the body maintain the foamy substance in position until it hardens. The egg-case is built of the foamy substance, which holds its shape just as it is being fashioned, and no more needs the tip of the body to support it until it hardens than a clay model needs to be held by the modeler until it becomes firm. The insect leaves the pile immediately after finishing the gradual slope downward. The structure maintains its form alone, but sometimes the material is soft enough to be crushed between the fingers for perhaps six hours after its completion. In so far as the use of the elytra is concerned, either in fashioning or supporting the case during its construction, any of the illustrations in this paper will show that the wings cover less than two-thirds of the length of the body and cannot by any means touch the egg-case while it is being built.

A female and her egg-case just a few hours after oviposition are shown in Pl. IX. This picture is about exact size; the case was the largest ever met with in my experience with the mantis, while that shown in Pl. X is the smallest. Attention is called to the size and shape of the abodmen of this female just after oviposition (Pl. IX) in contrast with the usual distended condition prior to oviposition, as seen in the lower female on Pl. IV. One wonders how so large a mass could have been packed in that body.

When the architecture of an egg-case is studied, with its rows of cells, galleries and openings all arranged with precision, one realizes the complexity of the task of building such a structure and wonders where the insect could have acquired this knowledge, since of course it had no mother or experienced contemporaries to mimic in nest building, as have the higher animals or even the social insects.

The work of nest making consumes about two hours, and almost always is commenced at sunset, or after dark. Why this strange time of day should almost invariably be chosen has not been ascertained.

When about to begin ovipositing the mantis takes its position on the twig or surface, head downward, holding on by the two hind pair of legs; the front pair are held free as usual. The insect remains perfectly quiet, excepting for the contractions and expansions of the last two or three abdominal segments. Soon a small stream or ribbon of whitish substance issues from the body; this in appearance greatly resembles tooth-paste as it is pressed from the tube. A little later, when it is worked up and ready for the making of the egg-case it is foamy and mucilagenous, like the beaten white of egg, and has a delicate greenish tint. When the ribbon protrudes for about a quarter of an inch, it is pressed against the twig or surface by the tip of the abdomen, and adheres thereto. Let it here be stated that throughout the work the insect rests with the head downward and has never been seen to turn to observe the work while in progress. Furthermore, none of the appendages assist in the egg-case making, but the mass of material is pumped from the body by the movements of the last two or three abdominal segments only, and the whole is shaped by the ovipositor, the two small cerci probably aiding in the construction by acting as sense organs.

The last two segments, by a series of contortions, contractions and expansions, press out the ribbon of ma-

terial, which soon is converted into the frothy substance. After it has reached the proper consistency under the manipulation of the ovipositor, it passes on into the pile ready to be fashioned into the beginning of the egg-case. During this process the ovipositor is much distended and attains great size; the opening also is very large under this condition.

The egg-case is begun at the broad, rounded end, and the construction progresses from side to side; each row of cells across the case is completed and the partition re-enforced before the next tier is begun. The ovipositor slowly works into the soft substance until quite a hollow space is formed; this forms one row of four cells on one side; then it passes on to make the corresponding suite on the other side. The dividing line between the right and left sides of the egg-case is indicated by the braided appearance on top. Evidently the eggs[16] are deposited during this hollowing-out process, and are embedded in the soft substance. They undoubtedly leave the body with this material, but never in all of my mantis experience could they be seen even with the closest scrutiny. While burrowing into the substance at the sides the ovipositor goes in more deeply, evidently to shape the lateral galleries. After a suite on each side has been completed some of the substance from the periphery is stretched over it to form a re-enforced partition between this and the next row of cells; this is perfected and smoothed by left and right strokes of the ovipositor. The insect then repeats the process, hollowing out and partition making until the whole is completed. One tier of cells is always complete, even to the little ribbon-like flap on top which is the door, before the hollowing out of the next tier commences. If the egg-case be large, the mother mantis will sometimes move a short distance downward as the structure grows. How the openings are made at the top during the construction

[16] The eggs are from 2 to 2½ mm. in length.

could never be discerned, but the cerci constantly pass over the last addition much in the manner that the antennae of some insects are used. Whether these organs assist in making the openings, or whether they act only as sense organs and keep the whole affair symmetrical could not be ascertained. In one female the cerci were removed with fine scissors during the egg-case building. The structure was completed in a very irregular manner. This fact may, however, have been the result of the shock of cutting, since the same individual without the cerci a few days later made another egg-case of perfectly normal appearance. The eggs are not deposited in a haphazard manner, but all of them stand on end, one in each cell. They must of course be embedded in this manner, and perhaps the cerci come into use in some way in accomplishing this. The last abdominal segment carrying the cerci is constantly in one position throughout the work, apparently always keeping hold upon the last addition of the "braided" top. From the opening just beneath the last dorsal segment the material for the nest issues, while the work of molding the cells and shaping the mass is done by the characteristic ovipositor. This organ goes over and smoothes each partition two or three times, while the dorsal tip never looses its hold of the last braided addition.

An interesting fact is that immediately after ovipositing the insect walks away for a short distance and goes through the contortion of forming a circle of her body, and with her head partly inserted into the rear opening eats away all that remains of the nest material, and in so far as I have been able to see, quite relishes it. It may be that it is necessary to remove any of this substance before it hardens and would be a great hindrance to future copulation or oviposition, but this cannot be the sole reason, for I have seen insects of both sexes behave in the same manner on other occasions, and the females usually just after mating.

The insect after leaving the egg-case usually pays no more attention to it.

In order to ascertain the nature and condition of this substance which goes into the egg-case while still in the body of the female, a number of insects about to oviposit were preserved in chloral hydrate and dissected—that is, the chitin covering the entire abdomen was carefully stripped off. The illustrations (Pl. XIV, Figs. 1 and 2) show the dorsal and ventral surface of the rows of whitish ribbon, which are connected with the eggs that lie just beneath; it is this ribbon-like material worked into froth, that go into the construction of the egg-case.

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EXPLANATION OF ILLUSTRATIONS.

Plate I.—A green female, showing the insect in act of moving head about. (Photograph from life.)

Plate II.—A male and female in copulo; showing the sexual diporphism of the species. (Photograph from life. Natural size.)

Plate III.—The male being devoured by the female while mating. (Natural size.)

Plate IV.—A group of adults. (Photograph from life.)

Plates V, VI, VIII.—Females and their natural environments. (Photograph from life. Natural size.)

Plate VII.—A dark gray and a green female in the attitude of fight. (Photograph from life.)

Plate IX.—A gray female and her egg-case. (Photograph from life.)

Plate X.—An abnormally small egg-case and its maker. (Photograph from life. Natural size.)

Plates XI, XII, XIII.—Nymphs in the fifth instar, showing the advantage of resemblance to environment. (Photograph from life. Slightly enlarged.)

Plate XIV.—A female with the integument removed, showing the ribbon-like substance, the material for egg-case making as it appears after hardening in chloral hydrate.—Fig. 1. Dorsal view.—Fig. 2. Ventral view. (Much enlarged.)

Plate XV.—Egg cases. (Slightly reduced.)

Plate XVI.—The structure of the egg-case.—Fig. 1. Horizontal section near botton (Floor).—Fig. 2. Horizontal section near top (Ceiling).—Figs. 3 and 4. Horizontal sections through the center.—Figs. 5 and 6. Longitudinal sections.—Figs. 7 and 8. Cross sections. (All enlarged.)

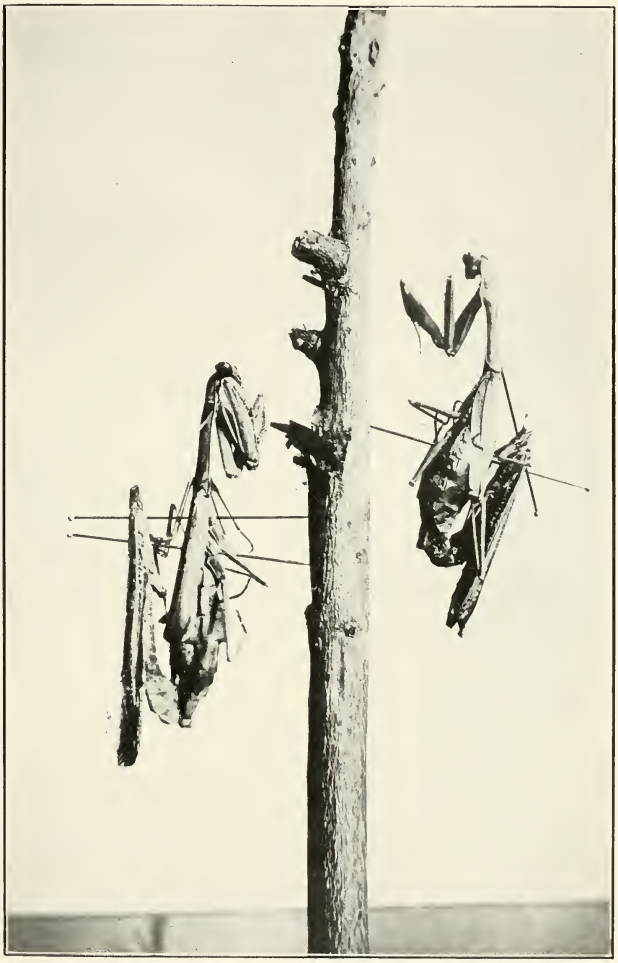
Plate XVII.—Nymphs just after emerging. (Greatly enlarged.)

Plate XVIII.—Fig. 1. Head, prothorax and forelegs of an adult female.—Fig. 2. A nymph going through its first moult. (Enlarged and ¾ natural size.)

Issued March 25, 1913.

STAGMOMANTIS CAROLINA.

STAGMOMANTIS CAROLINA.



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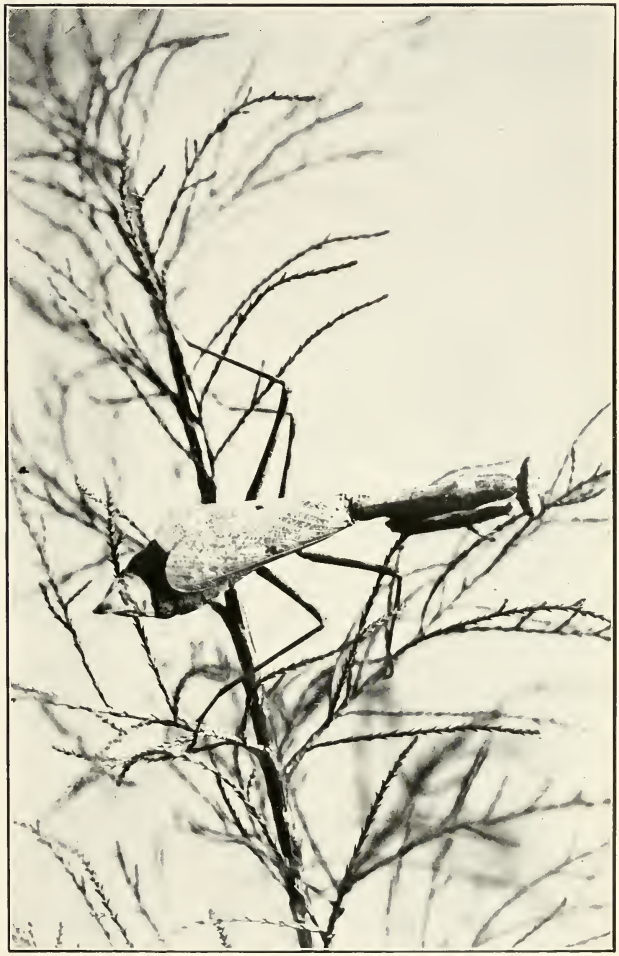

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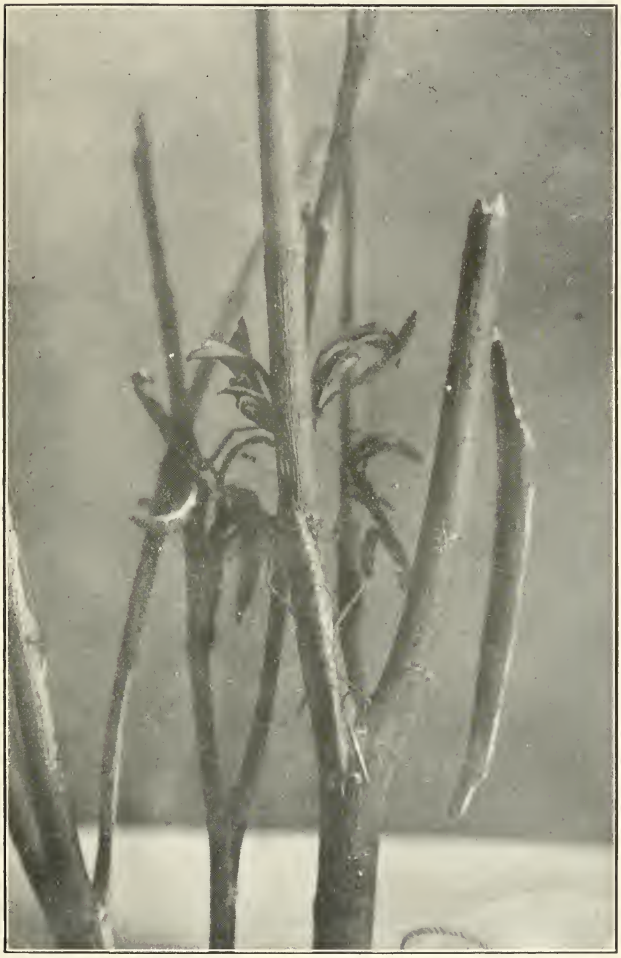

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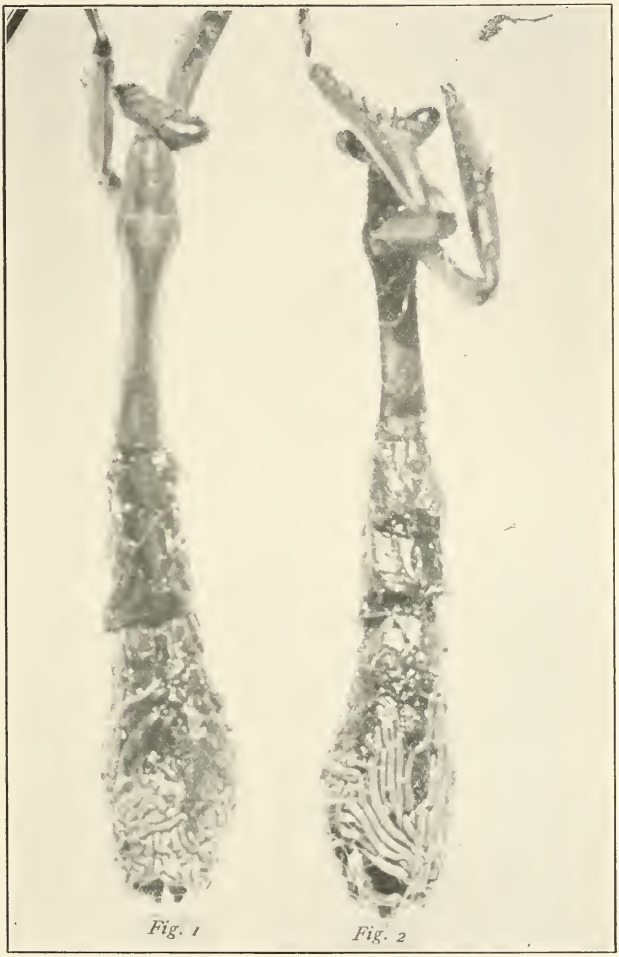
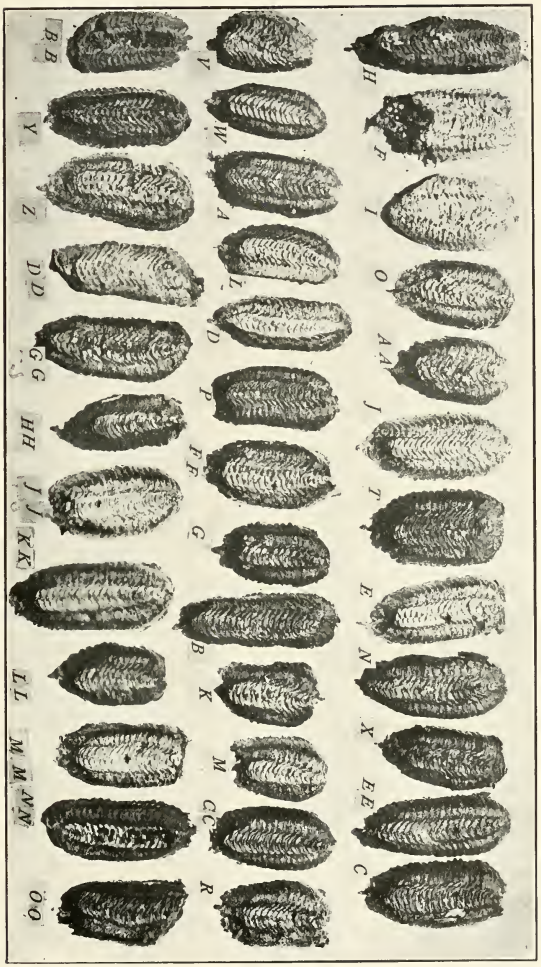


Fig. 1 *Fig. 2*

STAGMOMANTIS CAROLINA.



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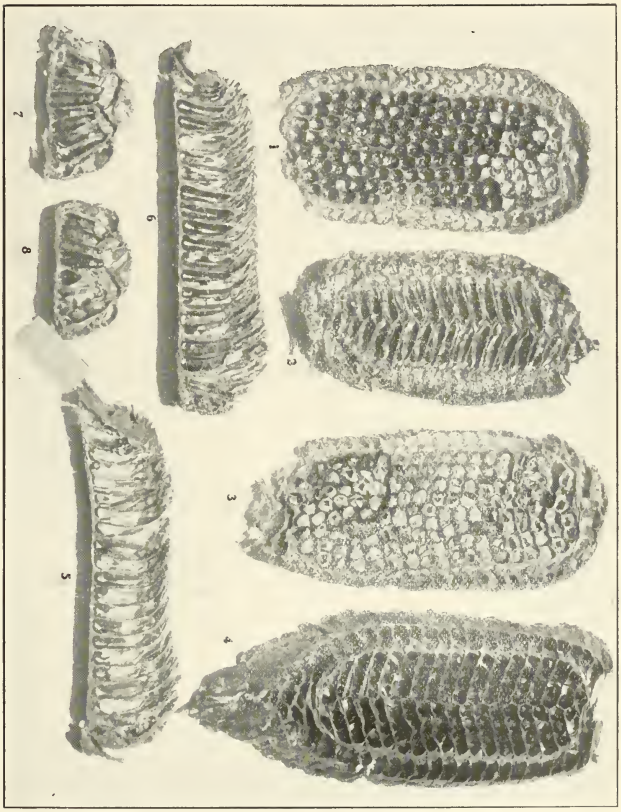

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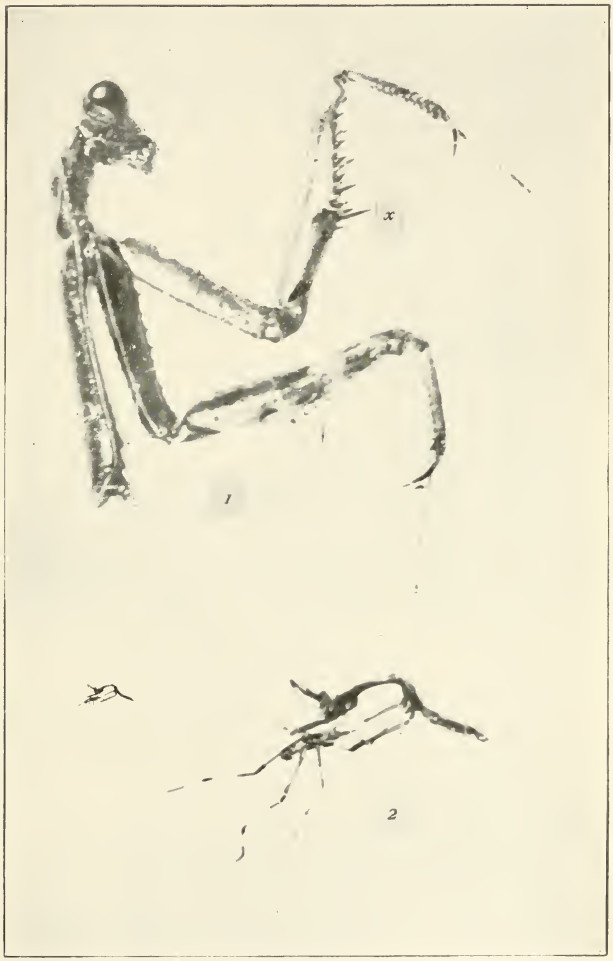

STAGMOMANTIS CAROLINA.

Transactions of The Academy of Science of St. Louis.

VOL. XXII. No. 2.

LOCAL MAGNETIC STORMS.

FRANCIS E. NIPHER.

Issued April 5, 1913.

LOCAL MAGNETIC STORMS.*

FRANCIS E. NIPHER.

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The work of the Ampère nearly a century ago, taken in connection with the fact that fragments of a steel magnet are also magnets, was sufficient grounds for the theory that the molecules of magnetic matter may contain closed electric currents. The discovery of the electron gave additional weight to the older suggestion. With a view of obtaining direct evidence of this condition within a steel magnet, the writer began a series of experiments which have led to interesting results, but which leave the original question unanswered.

It appeared possible that the magnetic force of a steel magnet might be varied by draining negative electrons from it. This was done by connecting it with the positive terminal of an influence machine.

The magnet to be tested was 30 cm. in length and about 2.5 cm. in diameter. It was composed of a thin film of steel 0.2 mm. in thickness. It was formed of a single layer of steel wire wound longitudinally on a piece of rubber hose, rendered rigid by means of a core of wood. The winding was in the form given the copper windings of a drum armature. The wire was held in place by silk cord, and the steel wire crossing the ends of the hose was removed. The wire was then magnetized.

This wire magnet was used as a deflecting magnet, being placed at right angles to a needle suspended on a silk fiber. The needle was wholly enclosed in a metal shield. A mirror attached to the suspension was observed through a glass window covered with copper wire gauze. A telescope and scale was used in observing deflections, one mm. having an angular value of 3′.4. The deflecting effect of the wire magnet was balanced by a

*Presented March 3, 1913.

OCT 9 - 1913

large bar magnet placed on the opposite side of the needle. The needle was rendered sensitive to changes in the turning moment of the wire magnet, by partially compensating the effect of the earth's field by means of bar magnets on either side of the needle. The time of a complete vibration in the earth's field within the building was the same, when all magnets were removed as when the opposing deflection magnets were in place, namely, 8.94 seconds. The compensating magnets increased the vibration period to 20 seconds.

It was found when either terminal of the influence machine in an adjoining room was connected with the insulated wire magnet, the other terminal being grounded, that the deflecting effect of this magnet was increased. The angle of deviation could not be determined with any precision, on account of fluctuations in the needle, but it amounted to about 15 minutes of arc. In some of the earlier experiments the reverse result was obtained. It was then concluded that the attraction between magnets, like that between masses of matter, depends upon their electrical potential. This question is, however, still an open one. It was found when the air around the magnet is rendered as quiet as possible, and when no disruptive effects are permitted along the conductor, that the magnet becomes apparently stronger. It was also found that disturbances of the air around the magnet appeared to diminish its deflection effect. It was found when the charged magnet was covered with tinfoil, that the change in the defection due to electrification was apparently unchanged. It was found when the air around the magnet was disturbed by the movement of an assistant, or by means of a palm-leaf fan, that its deflecting effect due to electrification was diminished. When the fan was operated during alternate semi-vibrations of the needle, the oscillations of the needle could be gradually increased in amplitude to five or six degrees of arc.

All of this evidence indicates conclusively, that the apparent increase in the strength of the deflecting magnet when in contact with the terminal of the machine, is due to an increase in the permeability of the air around the magnet.

The "charged" molecules of air appear to behave like iron filings, in that they set in the field of the deflecting magnet with the planes of the electrical whirls at right angles to the lines of force. It was found that a solid steel magnet gives similar results.*

The electrified magnet was placed in a glass tube having an internal diameter of about 4 cm. The tube extended to the metal shield enclosing the needle. This metal shield was grounded. It was then found that the deflecting effect of the magnet was less, than when the magnet was not connected with the influence machine. When the machine is stopped, the deflection at once becomes greater than normal, but it quickly diminishes to normal value. The reason for this was explained, by filling the tube with tobacco smoke before the machine was started. The column of air within the tube was in continual commotion while the machine was in operation. The molecules of ionized air could not then set in orderly array along the lines of force. It is remarkable that under such conditions, the permeability of the air-column is less, than when the magnet is not in communication with the machine.

When the insulated magnet was enclosed in a mass of cotton batting, having a diameter of about 50 cm.,

*A bar magnet thus used as a deflecting magnet, over which a sheet of glass is placed, extending to the shield around the needle, gives most interesting results when the plate is sprinkled with iron filings. The increase in permeability due to tapping the plate is plainly evident. When the filings are gathered in a heap at the equator of the magnet, its deflecting effect is greatly diminished. If at any point in the field of this magnet, the iron filings are disturbed by means of a brush, the magnetic field will be disturbed throughout. If the iron filings were free to move, they would respond to the disturbance. The suspended needle does respond.

electrification of the magnet had no appreciable effect upon its deflecting effect. The fibers of cotton then appear to determine the lines along which the ionized air-filaments shall form.

While observing the needle during a wind storm in which sudden and violent gusts of wind occurred, it was observed that the vibrations were affected in a marked way at the beginning of a wind-gust. The velocity of the needle would be suddenly and greatly changed. Several times it was observed that when it had come to rest at the extreme of a vibration, it would suddenly start into motion and in the direction in which it had been moving. Sometimes the velocity of swing would be greatly diminished, the motion would be arrested prematurely, and in the return swing, the velocity would be increased to a marked degree. These sudden changes in the motion of the needle occurred at the beginning of a gust of wind of unusual severity. In one case the unusual velocity of the wind persisted apparently unchanged for a couple of minutes, but the change in the motion of the needle occurred at the beginning of the gust. The amplitude of successive semi-vibrations would sometimes change from five minutes to half a degree, or the reverse. The amplitude was sometimes observed to gradually increase from zero to a maximum and then diminish again to zero. The maximum amplitudes were greatest when the wind was most violent and when it came in sudden gusts. On days when the wind was mild the maximum amplitude would not exceed one degree. On days of violent winds the amplitude has often risen to eight degrees. Notwithstanding the fact that the gusts of wind occur at irregular intervals, the variations in the amplitude of the needle resemble an irregular series of beats, as will be seen by reference to Plates XIX and XX.

The observations represented in these two plates were made on consecutive days, when the wind was unusually

violent. In Plate XIX the general direction of the wind was at right angles to the needle. On the next day the wind had shifted about 90°, and its direction was parallel to that of the needle. The compensating adjustments of the needle were the same in both cases, and the wind was no more violent on the second day than on the first. Plate XX.

The vertical lines represent the amplitude of oscillation in scale divisons. The lower end represents the scale reading to the left of the zero, and the upper end of each line represents the scale reading to the right. The observations of Plate XIX covered an interval of 1 h. 37 m. 38 s., during which time 290 to and fro oscillations occurred. The scale divisions were in millimeters, each having an angular value of 3.4 minutes of arc. The middle line represents the mean of the extreme readings of the scale. In Plate XX one hundred consecutive oscillations are represented.

The needle was made of tool steel having a diameter of ⅛ inch and a length of 3.5 inches. It was mounted in a wire clutch, and with it was placed a brass rod of about the same dimensions. This arrangement was adopted in order to tone down some of the irregularities shown in the vibrations of a highly magnetized needle made of a single small wire of steel, such as knitting wire.

The needle with small moment of inertia follows the variations in the earth's field more closely, but summation effects are occasionally obtained with the needle of larger moment, and the amplitude of vibration is thereby greatly increased.

These results are in all cases obtained when the earth's field is partly compensated, so that the changes are a large fraction of the resultant directive force.

It is of course understood that these observations do not indicate any change in the intensity of the earth's magnetic field, due to linear transfer of ionized air as

in the Rowland effect. They indicate a swaying of the lines of force, due to variations in permeability. They indicate that ionized molecules of air in the earth's magnetic field tend to set in definite position with respect to the lines of force. This would cause local variations in the position of the magnetic needle, and local and rapidly varying changes in intensity of the field. The local electrical condition of the air at the station of observation and at the moment when the wind-gust occurs is also involved.

Some visible evidence of auroral streamers have been obtained around the poles of a steel magnet. Satisfactory photographic evidence has not yet been obtained on account of the flickering character of the phenomena, and the inductive effects of the walls of the bell-jar in which the magnet is hung.

Plans are being made to repeat some of the work described in this paper, at the summer home of the writer, at the north end of Lake Huron, where the surroundings are those of Nature.

These observations were made in Eads Hall, a two-story building with granite walls, and floors of reinforced concrete. No vibrations of the building due to wind could have had any effect upon the observations. The only disturbances which complicated the results were those due to electric cars, and railway trains. Their effect was observed when that of the wind was inappreciable, and no effects comparable with those shown in Plates XIX and XX have ever been observed.

The tracks of these railways were about 650 feet distant.

Reversal of the Rowland Effect.

In a former paper in these Transactions, No. 3. Vol. XXI, this subject was discussed. The results there described have been obtained by suspending the wire shown in Fig. 1, p. 81, on three or four long silk fibers. The wire was placed in contact with vertical strips of hard

rubber, against which the wire was lightly pressed by small flexible bundles of hair. The wire is then slightly lifted when longitudinally displaced.

The discharge terminals were in the form of rings which encircled the wire near its ends, the ends being bent downwards outside of the ring terminals.

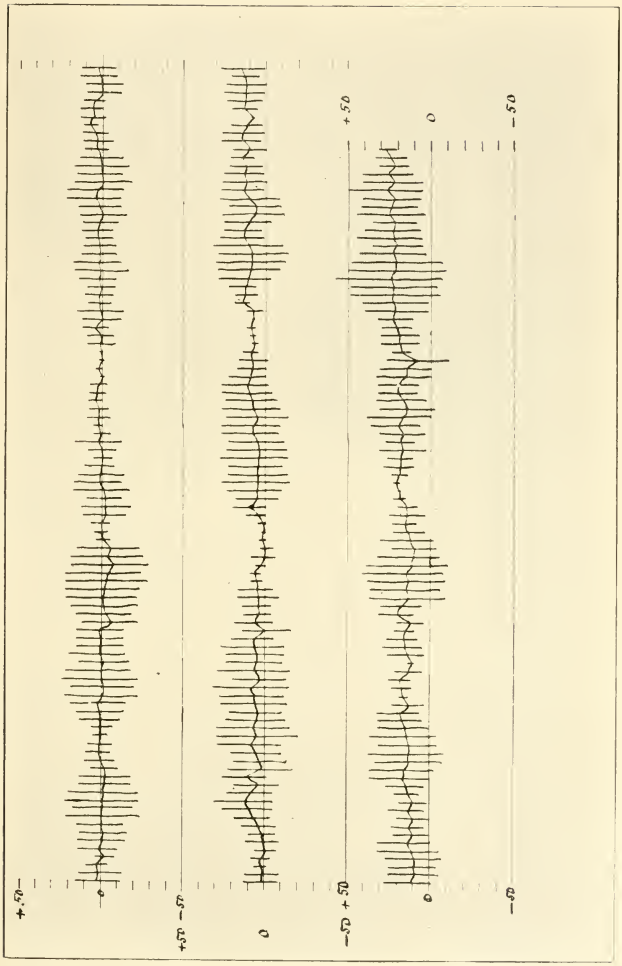
The air in the room must be very quiet, in order to prevent its effect upon the suspending fibers of silk. Such circulation as exists in a room heated by warm air interferes with the result. If the wire is placed in a tube as in Fig. 1 referred to above, the tube may be divided in half, and a pointer consisting of a fine fiber of glass, or a silk fiber, may be attached to the wire between the tubes. This serves as a mark upon which the telescope may be set, for observing the displacement. The support for the glass tubes must of course be provided with leveling screws.

EXPLANATIONS OF THE PLATES.

Plate XIX represents the amplitude and extreme scale readings of a magnetic needle during a wind storm, the effect of the earth's field being partly compensated by bar magnets. The resultant field was about 1/5 of H. The general direction of the wind was at right angles to that of the needle.

Plate XX, conditions as in Plate XIX, excepting that the wind direction was parallel to that of the needle. The effect on the needle is ascribed to wind-gusts which locally varied the permeability of the air, at fairly regular intervals.

Issued April 5, 1913.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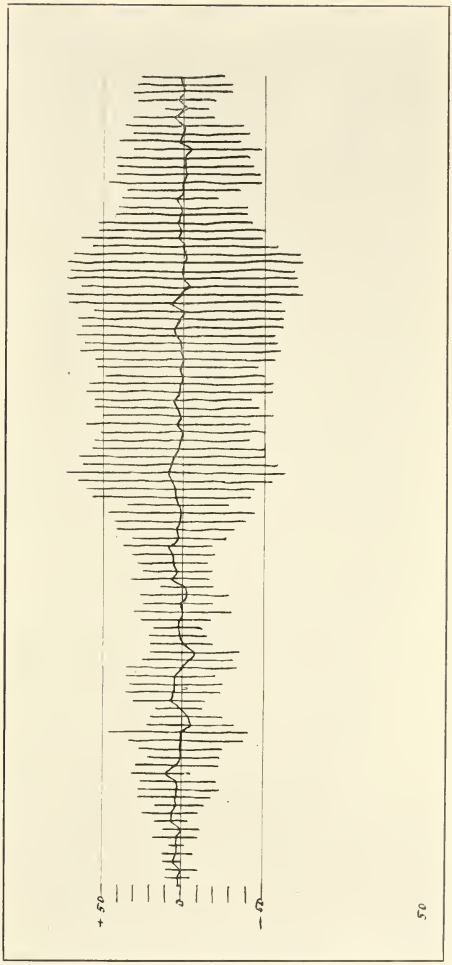
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Transactions of The Academy of Science of St. Louis.

VOL. XXII. No. 3.

A PRELIMINARY LIST OF THE MOLLUSCA OF MISSOURI.

(EXCLUSIVE OF THE UNIONIDÆ.)

F. A. SAMPSON.

Issued July 18, 1913.

A PRELIMINARY LIST OF THE MOLLUSCA OF MISSOURI (EXCLUSIVE OF THE UNIONIDÆ.)*

F. A. Sampson.

To this time no list of the shells of Missouri has been published. In many of the other States much more work has been done than in this. Baker's Catalog of the Mollusca of Illinois showed that ten counties in that State had been carefully listed, and records had from fifty-nine other counties. Lists of species had been published as early as 1854.

Five writers had published papers on the shells of Michigan, when in 1905 Bryant Walker gave a list of 272 species in that State. Of quite a number of other States lists have been published. In Missouri the author published a report on the shells of Pettis county, in the Kansas City Review of Science and Industry, and later in the Bulletin of the Sedalia Natural History Society, and published notes on some of the other counties of the State. Pilsbry and Ferriss collected in some of the southern counties of the State, but as a whole little has been done. The author interested Mr. O. A. Crandall, of Sedalia, a few years before his death, and he had collected in a number of the counties; his collection is now a part of the Bryant Walker collection in Detroit. The collecting of the author has been done in a hurry at odd hours while doing other work; and while extending into sixty-four counties, has approached thoroughness in but one. It is to be hoped that this paper will be the means of inducing a number of other persons to collect in their home localities, and communicate the results to the writer, that a more complete list

*Presented by title to The Academy of Science of St. Louis, June 2, 1913.

may be made. The present list contains 61 species and 12 varieties of land shells, and 46 species and 4 varieties of water shells.

Acknowledgments are due to Messrs. Bryant Walker, A. C. Billups, V. Sterki, F. C. Baker and B. Shimek for the identification of shells submitted to them.

Binney in his Manual of American Land Shells divides the United States into three provinces—the Pacific, Central and Eastern. The latter includes all of North America north of Mexico and east of the Rocky Mountains. It is divided into three regions, the Northern, Interior and Southern; Missouri is in the Interior Region. The Ozarkian fauna belongs to it, and is found in the Ozark Mountain regions of Missouri and south and west. This fauna contains some species which are peculiar to it, and others which have been derived from the Cumberland subregion, although the low lands between do not contain them; other species have come from the Texas subregion. That part of the Ozark region which is in Missouri does not have any species that is peculiar to that part of it. The State north of the Ozark region has, of course, many species that are found widely scattered in the Interior Region.

There have not been many new species and varieties described from Missouri. The following is the list:

Bulinus distortus Hald, St. Louis.
Bythinella aldrichi Call, Reynolds county.
Goniobasis potosiensis Lea, Potosi.
Goniobasis ozarkensis Call, Shannon county.
Lymnaea columella var. a Say, Cold Water creek.
Physa crandalli Baker, Pettis county.
Planorbis sampsoni Ancey, Pettis county.

The following list of species gives the counties in which the author has collected each, and shows in parenthesis the number of specimens from each locality in the collection of the author, it being in many cases the total number found. Reference is also made to reports of

other localities given by other authors. A total of 117 species and varieties is given, and a record of 900 localities.

Systematic Catalogue of Species.

Pelecypoda.

TELEODESMACEA.

Cyrenacea.

Sphæriidæ.

sphærium Scopoli.

1. Sphærium solidulum Prime.

   Jackson, Cape Girardeau Co.; Stream, Peirce City, Lawrence Co.; Lamar, Barton Co. (Resembles.)

2. Sphærium stamineum Conr.

   Marmaton River, Nevada, Vernon Co.

3. Sphærium stamineum forbesi Baker.

   McAllister Springs, Saline Co.; Flat Creek and Springfork, Pettis Co.

4. Sphærium striatinum Lam.

   Flat Creek and Springfork, Pettis Co.; Lamar, Barton Co.; Marmaton River, Nevada, Vernon Co.; McAllister Springs, Saline Co. (near); Sarcoxie, Jasper Co.; Dent Co.

musculium Link.

5. Musculium transversum Say.

   Lamar, Barton Co.; North River, Palmyra, Marion Co.; Jackson, Cape Girardeau Co.; Coon Creek, Jasper Co.; Flat Creek and Springfork, Pettis Co.

6. Musculium truncatum Lindsey.
   Pond, Flat Creek, Pettis Co.

7. Musculium securis Prime.
   Flat Creek, Pettis Co. (or near).

8. Musculium elevatum Hald.
   Coon Creek, Jasper Co.; Jackson, Cape Girardeau Co.; Pond, Flat Creek, Pettis Co.

pisidium Pfeifer.

9. Pisidium compressum Prime.
   Flat Creek, Pettis Co.

10. Pisidium frandulentum Sterki.
    Flat Creek, Pettis Co.

11. Pisidium noveborensis Prime.
    Flat Creek, Pettis Co. (near).

12. Pisidium neglectum Sterki.
    Branch of Muddy Creek, Pettis Co.

GASTROPODA.

Anisopleura.

PROSOBRANCHIATA.

Rhipidoglossa.

Helicinidæ.

helicina Lam.

13. Helicina orbiculata Say.
    Stone Co. (Pilsbry); Marble Cave, Stone Co. (Stearnes).

Shimek says this is not found north of the south line of Kentucky, either recent or fossil.

14. Helicina orbiculata tropica 'Jan.'

Jasper Co. (2); Barry Co. (9); Macdonald Co. (5); Seligman, Barry Co. (Pilsbry); Chadwick, Christian Co. (Pilsbry & Ferriss).

Postpliocene:—Providence, Boone Co. (8).

15. Helicina occulta Say.

Postpliocene:—Glasgow, Howard Co. (8); St. Joseph, Buchanan Co. (6); Kansas City, Jackson Co. (Shimek); Boonville, Cooper Co. (Shimek); St. Louis (Shimek).

Living specimens have been found in Iowa and some other States, but none have yet been recorded from this State.

Tænioglossa.

Viviparidæ.

vivipara Lam.

16. Vivipara contectoides W. G. Binney.

Binney in Part III of Land and Fresh Water Shells of North America says that this has been found in Missouri.

17. Vivipara intertexta Say.

Henry Co. (4).

campeloma Rafinesque.

18. Campeloma subsolidum Anth.

Petite Saline, Cooper Co. (4); Flat Creek, Pettis Co. (8), (1); Stomach of wild duck, Pettis Co. (14); Marmaton River, Nevada, Vernon Co. (3); Cow Skin River, Macdonald Co. (6); Grand Falls, Jasper Co. (1); Pond, Current River, Van Buren, Carter Co. (7); Black River, Poplar Bluffs, Butler Co. (5);

Big River, St. François Co. (1); Little River, Mo. (Call.); Dent Co. (15); Mississippi River, Pike Co. (5).

The collection has two reversed specimens from Pettis county.

19. Campeloma integra Say.

In his description of this species Say states that it inhabits the waters of the Missouri, but does not give any locality. However, according to Call it is not found in Missouri.

Amnicolidæ.

bythinella Moq-Tand.

20. Bythinella aldrichi Call.

Branch of Black River, Reynolds Co. (8).

These specimens were received from R. Ellsworth Call, and were a part of the original type lot. The species was described in the Bulletin of the Washburn College Laboratory of Natural History, December, 1886.

amnicola Gld. & Hald.

21. Amnicola parva Lea.

Flat Creek, Pettis Co. (175); Lamar, Barton Co. (1); Hinkston Creek, Columbia, Boone Co. (3).

22. Amnicola cincinnatiensis Lea.

Osage River, Cape Galena, Morgan Co. (1); Flat Creek, Pettis Co. (75); Jasper Co. (17), (13); Grand Falls, Jasper Co. (1); Marmaton River, Nevada, Vernon Co. (25); Gravois Mills, Morgan Co. (8); Lamar, Barton Co. (25); Peirce City, Lawrence Co. (angulate var.) (8); Lost Creek, Seneca, Newton Co. (angulate var.) (1).

23. Amnicola lapidaria Say.

Postpliocene:—Near St. Louis (Hambach).

pomatiopsis Tryon.

24. Pomatiopsis lapidaria Say.

Camden Co. (1).

In the collection of the Smithsonian Institution are specimens from St. Louis, with a query as to whether they were postpliocene. In Part II of the Land and Fresh Water Shells Binney states that the species is found from Missouri to Michigan.

Pleuroceridæ.

pleurocera Rafinesque.

25. Pleurocera elevatum Say.

Flat Creek, Barry Co. (6); Current River, Van Buren, Carter Co. (9); Black River, Poplar Bluffs, Butler Co. (13), South Missouri, (18); Center Creek, Sarcoxie, Jasper Co. (15).

26. Pleurocera elevatum lewisii Say.

Spring, Howell Co. (10).

27. Pleurocera subulare Lea.

Niangua River, Hahatonka, Camden Co. (2); James River, Galena, Stone Co. (2); Callaway Co. (Greger).

goniobasis Lea.

28. Goniobasis plebeius Anth.

Osage River, Cape Galena, Morgan Co. (12); Coffin Spring Branch, Morgan Co. (26); Gravois Creek, Morgan Co. (37); Branch Indian Creek, Morgan Co. (30); Mineral Branch, Mor-

gan Co. (16); Niangua River, Hahatonka, Camden Co. (15); Possum Creek, Camden Co. (21); Springfork, Camden Co. (52); Prairie Hollow Creek, Coellida, Camden Co. (13); Flat Creek, Pettis Co. (14); Shoal Creek, Barry Co. (15); Flat Creek, Barry Co. (6); Roaring River, Barry Co. (striped) (8); Same (light color) (9); Thatcher Branch, Benton Co. (14); Current River, Van Buren, Carter Co. (20); Mc—— Spring, Howell Co. (12); Teague Creek, Webster Co. (10); James River, Galena, Stone Co. (5); North Fork Soc River, Greene Co. (17); South Fork Soc River, Greene Co. (20); Center Creek, Sarcoxie, Lawrence Co. (13); Spring River, Verona, Lawrence Co. (20); Spring River, Carthage, Jasper Co. (20); Branch, Carthage, Jasper Co. (8); Lost Creek, Seneca, Newton Co. (17); Shoal Creek, Newton Co. (16); Cow Skin River, Macdonald Co. (18); Butler Creek, Noel, Macdonald Co. (9).

The genus Goniobasis is more widely distributed than the Pleurocera, and more species of it have been described than of the latter. As early as 1873 nearly five hundred species of Strepomatidæ had been described, they being exceedingly abundant in Tennessee and adjoining territory. At that time Tryon stated that the Mississippi river from its junction with the Ohio to its mouth seemed to have formed an insurmountable barrier to the dispersion of these shells. However in the same work he gave the types of one species from Potosi, Missouri, and of another from Saline county, Arkansas. This latter probably, under the name *sordida* was the one that he stated was found on both sides of the Mississippi. I cannot agree, however, that *plebeius* is a synonym of *sordida,* in which the whorls are convex, while in *plebeius* they are smooth and flattened, and the angle around the body whorl is generally present. These are also characteristics of *cubicoides,* a species described

from Indiana; one that was more likely to have extended to the west side of the Mississippi, than was one from Tennessee, the locality of *sordida*. But if the two names *plebeius* and *cubicoides* represent the same shell, the former has precedence in time of ten years, and consequently the latter is a synonym of the former.

There are noticeable differences in the Goniobases from different counties of Missouri, and if every minute difference made another species the list of names would perhaps not be small, but until this genus has been worked over thoroughly it is better to err in having too few names instead of too many.

Years ago some of the above shells were submitted to Mr. Tryon, and his decision was that they were *saffordi*, and that *cubicoides* and *plebeius* were both synonyms of *saffordi*.

29. Goniobasis livescens Menke.

Branch of Fox Creek, Douglas Co. (13); Branch of Gravois, Morgan Co. (10); Branch of Gravois below Mineral, Morgan Co. (14); Speer's Spring, Morgan Co. (25); Huff's Branch of Gravois, Morgan Co. (15); Mill Race, Gravois Mills, Morgan Co. (11); Clear Creek, Peirce City, Lawrence Co. (22); Jacks Falls, Current River, Carter Co. (Billups).

30. Goniobasis ozarkensis Call.

Blue Spring, Shannon Co. (4).

These specimens were received from R. Ellsworth Call, and were a part of the original type lot. The species was described in the same publication as *Bythinella aldrichi*.

31. Goniobasis depygis Say.

Jacks Falls, Current River, Carter Co. (Billups); Mississippi River, St. Louis (Billups); Spring Valley Creek, Shannon Co. (Billups).

32. Goniobasis potosiensis Lea.

King River, Potosi, Washington Co.; Carter Co. (Billups).

The type specimens of this species were from Potosi.

33. Goniobasis sordida Lea.

R. Ellsworth Call in Bulletin of Washburn College Laboratory gave a list of four species of Goniobasis found west of the Mississippi, and east of the Rocky Mountains, three of which were stated to be from Missouri, the above being one. He did not give the exact locality. See as to this also under *plebeius*.

34. Goniobasis cubicoides Anth.

This was one of the four species given by Call as found west of the Mississippi, but his specimens were no doubt what this report gives as *plebeius*.

Euthyneura.

PULMONATA.

BASOMMATOPHORA.

Hydrophila.

Physidæ.

physa Drap.

35. Physa anatina Lea.

Pond, Springfork, Pettis Co. (33); Nevada, Vernon Co. (5).

The Nevada specimens were thought by Pilsbry to be a "curious form of *albofilata*."

36. Physa gyrina Say.

From Pettis County:—Branch Flat Creek, May, 1883, (6); Pond, Flat Creek, May, 1883, (5); Sampson farm pond, Nov., 1883, (9); Same

place, Sept., 1885, (9); Stream, Gentry's, July, 1885, (12); Stream, n. w. Gentry's, May, 1885, (18); Walnut Creek, Oct. 1892, (33); Little Muddy Creek (49); Sedalia, Hildebrand pond (12); Crawford branch, Spring Fork (12); Small stream, Yankee's (24); Branch, Pin Hook bridge (15); Brown Spring Lake (9); East line of Co. (9); Pond, Spring fork Creek (3); Small pond, Flat Creek (4); Muddy Creek, Pin Hook bridge (15).

From Morgan County, Oct., 1891:—Porter Spring (15), (18); Branch, 4 miles from Versailles (3); Branch, Moreau (13); Mineral branch (9); Cave Spring (10).

From Barry County, Aug., 1891:—Shoal Creek (1); Mineral Spring (30); Roaring River Spring, July, 1891, (13); Same, June, 1891, (11); Spring near Roaring River Spring (12); Flat Creek, Cassville (27).

From Douglas County:—Spring on mountain (7); Spring, Livingston's (15); Branch Fox Creek (19); Clifty Creek (13); Branch (11).

From Camden County, Oct., 1891:—Wheeler's Spring (7); Camp Branch (17); Small Branch (13); Springfork Creek (11); Wainwright branch (4); Hahatonka Lake (15).

From Jasper County:—Shoal Creek, below Grand Falls (2); Spring, Sherwood (10); Coon Creek (10); Pond, Carthage (11).

Branch of Teague Creek, Webster Co. (20); Lost Creek, Seneca, Newton Co. (9); Butler Creek, Noel, Macdonald Co. (3); Moreau Creek, Moniteau Co. (9); Swamp, Scott Co. (14); La-

mar, Barton Co. (18); Pond, Nevada, Vernon Co. (7); Pond, Springfield, Greene Co. (13); Pond, Current River, Van Buren, Carter Co. (14); Greenfield, Dade Co. (6); New Madrid, New Madrid Co. (1); Black River, Poplar Bluff, Butler Co. (2); Branch St. François Co. (10); Big River, St. François Co. (5); Branch, Jackson, Cape Girardeau Co. (12); Stream, Aurora, Lawrence Co. (27); Godby's, Cooper Co. (10); Stone Co. (Stearns). Pond, Fern Glen, St. Louis Co. (10); Spring branch, Potosi, Washington Co. (32); Blees Academy lake, Macon, Macon Co. (18); Small branch, Chillicothe, Livingston Co. (23); Branch of Salt River, Paris, Marion Co. (23); Spring branch, Ironton, Iron Co. (20); Pond, Allanville, Cape Girardeau Co. (10); Spring branch, Ste. Genevieve, Ste. Genevieve Co. (45); Stream, Jackson, Cape Girardeau Co. (11); Pond, Rivermines, St. François Co. (20); Spring branch, Hannibal, Marion Co. (35); Callaway Co. (Greger); Dent Co. (15); Hinkston Creek, Boone Co. (12).

Postpliocene:—Below Platte river (Hambach).

Mr. O. A. Crandall, of the Missouri Trust Company of Sedalia, Missouri, on becoming a member of the American Conchological Society, in accordance with the plans of that society, adopted a specialty—the very difficult one of the American Physæ. He gave much investigation and study to the subject, and in July, 1901, he commenced the publication in the Nautilus of the results of his studies, during the publication of which he suddenly died. He examined and labelled all the Physæ that were then in my collection, and the present list is made in accordance with his determinations. Before that time I had supposed that some of the lots were *heterostropha,* but Mr. Crandall did not so identify any lot from Mis-

souri. His decision was that he had never seen any *heterostropha* from west of the Mississippi river.

37. Physa gyrina albofilata Ancey.

Cow Skin river, Macdonald Co., Aug., 1891, (8), (17); Nevada, Vernon Co.; Chadwick, Christian Co. (Pilsbry & Ferriss).

Some years ago I sent some Physa from Eureka Springs, Arkansas, to the late Mr. Ancey, then of France, and later of Algeria; these he described as *albofilata*. The same beautiful shells have been found in Missouri as above.

38. Physa oleacea Tryon.

Branch Cedar Creek, Pettis Co., Oct., 1883, (10); Pond, west of Gentry's, Pettis Co., May, 1885, (24); Pond, northwest of Gentry's, July, 1885, (14); Stream, Boonville, Cooper Co. (10); Pond on Gentry farm, Pettis Co. (15).

39. Physa integra Hald.

From Pettis County:—Flat Creek, Aug., 1886, (17); Same, Sept., 1886, (3); Muddy Creek, Aug., 1886, (14); Flat Creek, Aug., 1881, (40); Pond, Freight depot, Sedalia, Sept., 1884, (11); Same place, July, 1885, (15); Dresden, Sept., 1885, (15); Muddy Creek, Pin Hook, Apr., 1891, (15).

Hannibal, Marion Co., Sept., 1885, (15); Palmyra, Marion Co., Sept., 1887, (16); Kansas City, Jackson Co. (17); Bear Creek, Marion Co. (25); Lake, Peirce City, Lawrence Co., 1880, (29); Same, April, 1884, (20); Spring, Nevada, Vernon Co., Aug., 1884, (25); Pond, Nevada, Aug., 1884, (14); Branch, Columbia, Boone Co., April, 1903, (26); Same, May, 1903, (16).

40. Physa integra halei Lea.

Small stream, Peirce City, Lawrence Co., Sept., 1887, (7).

So identified by Pilsbry.

41. Physa grovenori Lea.

From Pettis County:—Crandall's fountain, Sedalia (20); Slough, Flat Creek, July, 1883, (16); Pond, E. Brown's, Sept., 1884, (10); Branch, Springfork (50); Pond, Georgetown, June, 1885, (35); McNutt's Branch, Pin Hook, April, 1891, (15); Springfork, Aug., 1881, (35). Lake, Peirce City, Lawrence Co., June, 1881, (35); Lake, Mountain Grove, Wright Co. (4); Pool, Cow Skin River, Macdonald Co., July, 1891, (3); Nevada, Vernon Co., Aug., 1884, (30); Williamsville, Wayne Co., 1889, (14); Blue Lick Springs, Saline Co., 1892, (34).

42. Physa crandelli Baker

Clear and Muddy Creeks, Pettis Co.

This was described by Mr. Crandall as *Physa rhomboidea,* but as that name was preoccupied, it was changed as above by Mr. Baker.

43. Physa plicata DeKay.

Near Mouth of Wolf River (Hambach).

44. Physa elongata Say.

Mouth of Platte River (Hambach).

Ancylidæ.

ancylus Geoffroy.

45. Ancylus kirklandi Walker.

Muddy Creek, Pettis Co., 1886, (8); Flat Creek, Pettis Co. (16); Same, Aug., 1886, (25); Osage

River, Cape Galena, Morgan Co. (12); Peirce City, Lawrence Co. (10); Center Creek, Sarcoxie, Jasper Co. (7); Grand Falls, Jasper Co. (2); Cow Skin River, Macdonald Co. (2).

46. Ancylus rivularis Say.

Jasper Co. (8); Peirce City, Lawrence Co. (3).

Planorbinæ.

planorbis Müller.

47. Planorbis bicarinatus Say.

Flat Creek, Pettis Co. (25); Pond, Flat Creek (12); Crandall's fountain, Sedalia, Pettis Co. (13); Cooper Co. (3); Lamar, Barton Co. (1); Lake, Mountain Grove, Wright Co. (2); Spring branch, Hannibal, Marion Co. (23); Callaway Co. (Greger); Blees Academy lake, Macon, Macon Co. (13).

48. Planorbis trivolvis Say.

Flat Creek, Pettis Co. (15); Pond, Pettis Co. (6); Pond, E. Brown's, Pettis Co. (7); Pin Hook, Muddy Creek, Pettis Co. (4); Cave Spring, Morgan Co. (8); Roaring River, Barry Co. (9); Lake, Mountain Grove, Wright Co. (7); Pond, Current River, Van Buren, Carter Co. (7); Branch, Spring River, Carthage, Jasper Co. (6); Stream, Peirce City, Lawrence Co. (10); Lake, Peirce City (15); Nevada, Vernon Co. (5); Daviess Co. (6); Cooper Co. (7); Swamp, Scott Co. (6); Springfork Creek, Camden Co. (14); Grand Falls, Jasper Co. (3); Lake, Clinton, Henry Co. (13); Callaway Co. (Greger); Blees Academy lake, Macon, Macon Co. (9).

Postpliocene:—Bluff City Landing (Hambach).

49. Planorbis sampsoni Ancey.

Pond, Flat Creek, Pettis Co., type lot (4); Same place, May, 1883, (3); Same place, Aug., 1886, (25); Same place, July, 1889, (15); Flat Creek, Pettis Co. (6); Bowsher's Spring, Mercer Co. (3); Coelleda, Camden Co. (1).

For some years this species was abundant in a pond on Flat Creek near Sedalia, from which the type specimens came, but when the locality of the pond was put in cultivation the pond dried up and that locality was exhausted. A few specimens have been found in Flat Creek near by, a single one in Camden county, a larger size in a spring in Mercer county, some at Athens, in Illinois, and lately at one place in Arkansas.

50. Planorbis exacuous Say.

Pond, Flat Creek, Pettis Co. (68).

This and the next were found in the same small pond with *Planorbis sampsoni.*

51. Planorbis parvus Say.

Pond, Pettis Co. (21).

52. Planorbis armigerus Say.

Mouth of Wolf River (Hambach).

Lymnæidæ.

Lymnæinæ.

pseudosuccinea Baker

51. Pseudosuccinea columella Say.

Flat Creek, Pettis Co., 1881, (7); Lake, Mountain Grove, Wright Co. (1); Pettis Co. (8); Branch of Spring River, Carthage, Jasper Co. (1).

52. Pseudosuccinea columella chalybea Gld.

Crandall's fountain, Sedalia, Pettis Co., 1882, (29); Flat Creek, Pettis Co., 1884, (13); Blees Academy lake, Macon, Mo. (3).

53. Pseudosuccinea columella casta Lea.

Branch of Flat Creek, Pettis Co. (1).

galba Schrank.

54. Galba bulimoides techella Hald.

Spring on bluffs, Kansas City, Jackson Co. (25).

55. Galba parva Lea.

Flat Creek, Pettis Co. (4); Pettis Co. (4); Leucke's quarry, Pettis Co. (6); Springfield, Greene Co. (12); Branch, Pettis Co., May 30, 1885, (7).

56. Galba humilis modicella Say.

Stream, Peirce City, Lawrence Co. (4); Coelleda, Camden Co. (15); Springfork, Pettis Co. (26).

57. Galba obrussa Say.

Livingston's pond, Douglas Co. (11); Spring Branch, Douglas Co. (24); Spring Branch, Ste. Genevieve Co. (6); Lamar, Barton Co. (3); Branch, Madison Co. (1); Pond, Peirce City, Lawrence Co. (3); Roaring River Spring, Barry Co., 1881, (10).

58. Galba obrussa exigua Lea.

Roaring River Spring, Barry Co. (14).

59. Galba catascopium Say.

Flat Creek, Pettis Co. (1).

Acteophila.

Auriculidæ.

carychium Müller.

60. Carychium exiguum Say.

Sedalia, Pettis Co. (10); Providence, Boone Co. (100).

61. Carychium exile H. C. Lea.

Providence, Boone Co. (25).

STYLOMMATOPHORA. Monotremata, Vasopulmonata, Orthurethra.

Valloniidæ.

vallonia Risso.

62. Vallonia pulchella Müll.

Sedalia, Pettis Co. (50); Providence, Boone Co. (75); Columbia, Boone Co. (50).

In Sedalia at the crossing of the two principal streets, a vacant lot had stones piled upon it, and for a time this shell was found there in great numbers. At Providence, in local drift by the side of the railroad tracks, in about a quart of material, I found this and a large number of other small shells, in all more than a thousand shells. Postpliocene fossils were abundant close by, but I could not find any of these small ones imbedded in the ground with the fossils, and think they were of living shells, though most of them were bleached.

63. Vallonia gracilicosta Reeve.

Providence, Boone Co. (7).

64. Vallonia parvula Sterki.

Providence, Boone Co. (10).

Pupidæ.

strobilops Pils.

65. Strobilops labyrinthica Say.

Sedalia, Pettis Co. (15); Providence, Boone Co. (100); Nevada, Vernon Co. (2); Lamar, Barton Co. (2); Morgan Co. (1); St. François Co. (2); Camden Co. (3); Jaspar Co. (5); Columbia, Boone Co. (2); Callaway Co. (Greger).

Postpliocene:—St. Louis (Hambach).

pupoides Pfeiffer.

66. Pupoides marginata Say.

Sedalia, Pettis Co. (200); Jasper Co. (24); Springfield, Greene Co. (4); Ash Grove, Same Co. (3); Nevada, Vernon Co. (10); Seligman, Barry Co. (25); Galena, Stone Co. (33); Washington Co. (5); Iron Mt., St. François Co. (4); Jackson, Cape Girardeau Co. (1); Camden Co. (20); Greenfield, Dade Co. (12); Mt. Vernon, Lawrence Co. (3); Chouteau Springs, Cooper Co. (1); Columbia, Boone Co. (35); Paris, Monroe Co. (4); Jefferson City, Cole Co. (3); Fern Glen, St. Louis Co. (1); Callaway Co. (Greger); Gallatin, Daviess Co. (5).

bifidaria Sterki.

67. Bifidaria armifera Say.

Sedalia, Pettis Co. (63); Jasper Co. (11); Springfield, Greene Co. (4); Ash Grove, Same

Co. (2); Nevada, Vernon Co. (15); Monett, Lawrence Co. (3); Warrensburg, Johnson Co. (1); Warsaw, Benton Co. (2); Morgan Co. (1); California, Moniteau Co. (7); Columbia, Boone Co. (24); Chouteau Springs, Cooper Co. (6); Jefferson City, Cole Co. (18); Macdonald Co. (1); Greenfield, Dade Co. (4); Camden Co. (27); Golden City, Barton Co. (2); Cassville, Barry Co. (1); Douglas Co. (21); Iron Mt., St. François Co. (17); Potosi, Washington Co. (1); Paris, Monroe Co. (15); Fern Glen, St. Louis Co. (10); Seligman, Barry Co. (Pilsbry); Chadwick, Christian Co. (Pils. & Ferriss); Callaway Co. (Greger); Gallatin, Daviess Co. (5).

Postpliocene:—St. Joseph, Buchanan Co. (1); Near St. Louis (Hambach).

68. Bifidaria contracta Say.

Sedalia, Pettis Co. (25); Lamar, Barton Co. (15); Golden City, Same Co. (56); Nevada, Vernon Co. (3); Jasper Co. (15); Springfield, Greene Co. (1); Warsaw, Benton Co. (1); Moniteau Co. (5); Columbia, Boone Co. (4); Camden Co. (3); Paris, Monroe Co. (1); Chouteau Springs, Cooper Co. (1); Providence, Boone Co. (225); Iron Mt., St. François Co. (5); Seligman, Barry Co. (Pils.).

69. Bifidaria pentodon Say.

Warsaw, Benton Co. (1); Sedalia, Pettis Co. (13); Lamar, Barton Co. (5); Camden Co. (1); Jasper Co. (Vanatta & Pils.).

70. Bifidaria pentodon floridana Dall.

Lamar, Barton Co. (1).

71. Bifidaria holzingeri Sterki.

Jasper Co. (1); Providence, Boone Co. (40).

72. Bifidaria procera Gld.

Sedalia, Pettis Co. (25); Nevada, Vernon Co. (var.) (1); Providence, Boone Co. (54); Jefferson City, Cole Co. (2).

vertigo Mull.

73. Vertigo gouldii Binney.

Providence, Boone Co. (11).

Cochlicopidæ.

cochlicopa Fer.

74. Cochlicopa lubrica Müll.

Seligman, Barry Co. (Pils.).

HETERURETHA.

Elasmognatha.

Succineidæ.

succinea Drap.

75. Succinea ovalis Say.

Providence, Boone Co. (4), (4); Callaway Co. (Greger).

Postpliocene:—Glasgow, Howard Co. (var.) (5); Bluff City Landing (Hambach).

One lot from Providence was from low ground in the river bottom, and the shells were 18 mm. long.

76. Succinea retusa Lea.

Columbia, Boone Co. (3); Barry Co. (2); Saline Co. (8).

77. Succinea avara Say.

Near Georgetown, Pettis Co. (6), (11); Flat Creek, Same Co. (11); Columbia, Boone Co. (13); Chouteau Springs, Cooper Co. (9); Porter Springs, Morgan Co. (5); Camden Co. (1); Springfield, Greene Co. (3); Jackson, Cape Girardeau Co. (4).

Postpliocene:—Glasgow, Howard Co. (3).

78. Succinea avara vermeta Lea.

Columbia, Boone Co. (8).

79. Succinea grovenori Lea.

Iron Mountain, St. François Co. (1); Carthage, Jasper Co. (1); Columbia, Boone Co. (17); Pettis Co. (9); Same Co., July 4, 1883, (4); Georgetown, Same Co., May, 1884, (24).

Postpliocene:—St. Joseph, Buchanan Co. (Extreme form) (6); very large form (10).

80. Succinea concordialis Gld.

Sedalia, Pettis Co. (23); Muddy bridge, Georgetown, Same Co. (13); Pettis Co., May, 1883, (18); Columbia, Boone Co. (11); Golden City, Barton Co. (1); Jackson, Cape Girardeau Co. (1); Providence, Boone Co. (3).

81. Succinea obliqua Say.

Bluff City Landing (Hambach).

82. Succinea campestris Say.

Bluff City Landing (Hambach).

Holopoda.

Helicidæ.

polygyra Say.

83. Polygyra leporina Gould.

Monett, Barry Co. (2); Cape Girardeau Co. (2); Neeleyville, Butler Co. (2).

84. Polygyra fraudulenta Pils.

Fern Glen, St. Louis Co. (15); Allanville, Cape Girardeau Co. (3); Kimmswick, Jefferson Co. (1).

The peristome is not reflected backward and rounded as in *neglecta,* but is widely reflected and directed inwards forming a basin-shaped mouth. The upper tooth on the lip is the broader, and generally slightly bifid, and is on the edge, contrary to the type description. The specimens are 13 to 17 mm. diameter, and in one case, in which a shell had been injured and repaired, only 12 mm. The only difference between these and *neglecta* seems to be in the size and the diameter of the umbilicus. In these the umbilicus extends to the apex of the first whorl, but it is not wide enough to see the whorls to the apex, while in *neglecta* it is. The Allanville shells are the larger, up to 17½ mm. diameter. All are flatter than Indiana specimens.

85. Polygyra neglecta Pils.

Carthage, Jasper Co. (7); Cassville, Barry Co. (12); Seligman, Barry Co. (P & F.); Springfield, Greene Co. (P. & F.); Chadwick, Christian Co. (P. & F.).

Many of the specimens at Eureka Springs, Arkansas, are albinos, but this is not often the case with the Missouri shells. At Cassville they were 10 to 10½ mm. diameter, but from Carthage they were markedly larger, 12 to 13 mm. The inferior lip tooth is somewhat the larger, is more prominent on the front part of the lip, and in some cases is bifid.

86. Polygyra vultuosa Gould.

Sedalia, Pettis Co.; Boonville, Cooper Co. (1).

Years ago I found on Flat Creek near Sedalia, a single shell that I with another compared very carefully with this species, and had no doubt of the identification, but the specimen has been lost. A single shell in the collection is marked with a question mark as from Boonville. In a later hunt I hoped to find another but did not do so. The shell is not quite mature, but is believed to be this species.

87. Polygyra crageni Call.

Dade Co. (1); Split Log, Macdonald Co. (1); Mt. Vernon, Lawrence Co. (1).

These would formerly have been included in *vultuosa,* but are now separated under the above name.

88. Polygyra inflecta Say.

Poplar Bluff, Butler Co. (7); St. François Co. (3); Marble Hill, Bollinger Co. (3); Madison Co. (3); Seligman, Barry Co. (7); Fern Glen, St. Louis Co. (3); River Bluffs, Moniteau Co. (10); Providence, Boone Co. (5); Boonville, Cooper Co. (21); Camden Co. (2); Morgan Co. (9); Sedalia, Pettis Co. (14); Warsaw, Benton Co. (10); Galena, Stone Co. (6); Carthage, Jasper Co. (15); Macdonald Co. (7); Chadwick, Christian Co. (Pilsbry & Ferriss); Cure-

all Springs, Howell Co. (Walker Coll.); Jefferson City, Cole Co. (Walker Coll.); Ironton, Iron Co. (1); Cape Girardeau, Cape Girardeau Co. (?); Ste. Genevieve, Ste. Genevieve Co. (2); Callaway Co. (Greger).

Postpliocene:—Providence, Boone Co. (12).

89. Polygyra inflecta media Pils.

Pilsbry reports finding at Seligman specimens with normal teeth and also with teeth very much reduced, which he called variety *media*. All the shells I found there have normal teeth.

90. Polygyra profunda Say.

Postpliocene:—Providence, Boone Co. (10); Lupus, Moniteau Co. (10); Lexington, Lafayette Co. (Hambach).

I have not found living specimens of this species in the State.

91. Polygyra albolabris Say.

Postpliocene:—One-half mile below Great Nemaha (Hambach).

92. Polygyra albolabris alleni Weth.

Pettis Co. (11); Jefferson City, Cole Co. (3); McAllister Springs, Saline Co. (5); Camden Co. (3); Morgan Co. (2); Warsaw, Benton Co. (3); Columbia, Boone Co. (13); Kansas City, Jackson Co. (4), (19); Barry Co. (2); Scott Co. (1); Madison Co. (1); Shepard Mountain, Iron Co. (1); Cape Girardeau, Cape Girardeau Co. (6); Galena, Stone Co. (3); River bluffs, Moniteau Co. (3); Birmingham, Clay Co. (6); Chadwick, Christian Co. (Pils. & Fer.); Selig-

man and Monett, Barry Co. (P. & F.); DeSoto, Jefferson Co. (Pils.); Bethany, Harrison Co. (Walker Coll.); St. Charles Co. (4).

Postpliocene:—Lupus, Moniteau Co. (7); Providence, Boone Co. (10).

The specimens very generally show the characteristics of the variety *alleni*. Those from one locality in Kansas City are noticeable for their small size. The following will show the sizes of some found in an old cemetery, and of some dead shells found on the bluff above the Union station:

Diameter.	Cemetery.	Bluffs.
18 mm.	2	
18.5	2	
19	11	
19.5	7	
20	20	1
20.5	8	
21	16	
21.5	6	
22	7	
22.5	5	
23	5	1
23.5	1	2
24	1	1
24.5		1
25	1	1
27		1

From Galena the specimens were from 26 to 30 mm. diameter; from Scott county 32 mm., and the postpliocene from Providence 23 to 33 mm.

93. Polygyra divesta Gould.

Dade Co. (5); Seligman, Barry Co. (1); Carthage, Jasper Co. (3); Camden Co. (1); Chadwick, Christian Co. (Pilsbry); Springfield, Greene Co. (Pils.); Cedar Gap, Wright Co. (Pils.); Mt. Vernon, Lawrence Co. (Walker Coll.).

Postpliocene:—St. Joseph, Buchanan Co. (5).

94. Polygyra zaleta Binney.

Fern Glen, St. Louis Co. (9); Vineland, Jefferson Co.

Those from Fern Glen could not be distinguished from Ohio specimens if mixed with them. They are up to 29 mm. diameter. In 1898 Frank C. Baker identified some shells collected at Arcadia, among them *Polygyra zaleta.* Whether these were the present *zaleta* or the *zaleta ozarkensis* is uncertain.

95. Polygyra zaleta ozarkensis Pils.

Columbia, Boone Co. (1); Moniteau Co. (1); Camden Co. (3); Roaring River, Barry Co. (1); Cassville, Barry Co. (2); Macdonald Co. (2); Galena, Stone Co. (4); Current river, county not given, (Pils. & Fer.); Cedar Gap, Wright Co. (Pils. & Fer.); Chadwick, Christian Co. (Pils. & Fer.); Springfield, Greene Co. (Weller); St. François Co. (Walker Coll.).

96. Polygyra multilineata Say.

Boonville, Cooper Co. (1).

In August, 1911, I found a single dead but fresh shell on the river bluff above the bridge at Boonville, the only one I have found in the State. It is 20 mm. in diameter.

Postpliocene:—Glasgow, Howard Co. (4); Near Mouth of Big Nemaha and Platte rivers (Hambach).

97. Polygyra appressa Say.

New Madrid Co. (7); River bottom, Scott Co. (1); Benton, Scott Co. (7); Poplar Bluff, Butler Co. (2); St. François Co. (2); Madison Co. (3); Cape Girardeau, Cape Girardeau Co. (11); Allanville, Cape Girardeau Co. (13); Ste. Genevieve, Ste. Genevieve Co. (17); Kimmswick,

Jefferson Co. (1); Fern Glen, St. Louis Co. (5); Morgan Co. (6); Jefferson City, Cole Co. (14); River bluffs, Moniteau Co. (13); McBaine, Boone Co. (9); Providence, Boone Co. (7); Boonville, Cooper Co. (28); Bear Creek, Marion Co. (20); Pineville, Macdonald Co. (Walker Coll.); Pettis Co. (Walker Coll.); Arcadia, Iron Co. (Baker); St. Louis (Smithsonian Coll.); Callaway Co. (Greger).

Postpliocene:—Providence, Boone Co. (22), (12); Lupus, Moniteau Co. (15).

Those from the southern counties are of heavier and coarser striæ than the others, but the specimens from the river bottom in Scott county have much less prominent striæ than those from Benton in the same county. In all of the lots are found specimens with a single lip tooth, and others with two, and sometimes one without either. Pilsbry has defined *appressa* (Nautilus, Volume VII, p. 140) as having no microscopic spiral lines, but this was criticised by Wetherby. However, in none of the above are found the microscopic lines as given in the type description.

Those from New Madrid county are the largest, 17 to 21 mm.; from Jefferson City they are 15 to 16 mm., with fine striæ. From the river bluffs in Moniteau county one would expect the same size as at Jefferson City, but they are distinctly larger, 16 to 18 mm. At Boonville, also on the Missouri river, they are from 14 mm., and a number of the shells do not have the umbilicus covered. This is markedly so also of a shell from St. François county. From Ste. Genevieve the shells are very much like those from central Missouri. The Cape Girardeau shells vary from the small, light colored, very finely striated, to the larger dark colored coarsely striated form. One shell shows that by some injury a part of the shell was broken away, and a new lip more than a half whorl short of the original one formed. Both teeth remain, the old one

more than a half whorl beyond the later one. The Allanville shells resemble the larger of those from Cape Girardeau, but are distinctly different, and of a deeper reddish color. Pilsbry says he has seen some Arkansas and Illinois specimens similar but not so dark.

The postpliocene shells from Providence vary from 15 to 21½ mm. diameter.

98. Polygyra elevata Say.

Bear Creek, Marion Co. (8); Jefferson City, Cole Co. (3); Barry Co. (1); Camden Co. (4); Columbia, Boone Co. (6); Moniteau Co. (1); Galena, Stone Co. (7); Fern Glen, St. Louis Co. (2); Pettis Co. (Walker Coll.); Springfield, Greene Co. (Walker Coll.); Callaway Co. (Gregger); St. Charles Co. (3); Missouri City, Clay Co. (1).

Postpliocene:—Lupus, Moniteau Co. (11); Providence, Boone Co. (15).

99. Polygyra pennsylvanica Greene.

Jackson, Cape Girardeau Co. (1); Fern Glen, St. Louis Co. (1).

Postpliocene:—Providence, Boone Co. (4).

The Fern Glen shell looks very much like a postpliocene fossil, but I think it is not such.

100. Polygyra thyroides Say.

Scott Co., upland, (1); Same, river bottom, (7); Jackson, Cape Girardeau Co. (2); St. François Co. (4); Marble Hill, Bollinger Co. (2); Poplar Bluff, Butler Co. (4); New Madrid Co. (2); Van Buren, Carter Co. (1); Camden Co. (3); Morgan Co. (1); Moniteau Co. (6); Boonville, Cooper Co. (11); Pettis Co. (10), (1); Carthage,

Jasper Co. (3), (2); Columbia, Boone Co. (10); McAllister Springs, Saline Co. (1); Bear Creek, Marion Co. (2); Galena, Stone Co. (1); Fern Glen, St. Louis Co. (2); Seligman, Barry Co. (Pils.); Chadwick, Christian Co. (Pils.); Birmingham, Clay Co. (4); Rockville, Bates Co. (Walker Coll.); Cureall Springs, Howell Co. (Walker Coll.); Vineland, Jefferson Co. (Baker); Tuscumbia, Miller Co. (1); North Jefferson, Calloway Co. (3).

Postpliocene:—Lupus, Moniteau Co. (1); Providence, Boone Co. (12); Bluff City Landing (Hambach).

From the river bluffs at Boonville they are uniformly small in size; from Boone county they are 20 to 26 mm. in diameter, and from Scott county up to 27 mm.

101. Polygyra clausa Say.

Barry Co. (3); Cassville, Barry Co. (5); Springfield, Greene Co. (2); Peirce City, Lawrence Co. (10); Carthage, Jasper Co. (7); Douglas Co. (2); Dade Co. (1); Pettis Co. (10); Kansas City, Jackson Co. (4); Blue Lick, Saline Co. (2); Jackson, Cape Girardeau Co. (1); Boonville, Cooper Co. (3); Birmingham, Clay Co. (13); Galena, Stone Co. (2); Fern Glen, St. Louis Co. (3); Chadwick, Christian Co. (Pils. & Fer.); St. Louis (Lind.); Arcadia, Iron Co. (Baker); Callaway Co. (Greger); Dent Co. (7); St. Charles Co. (1).

Postpliocene:—Providence, Boone Co. (2); Near mouth of Big Nemaha and Platte rivers (Hambach).

102. Polygyra labrosa Bland.

Macdonald Co. (6); Dade Co. (6); Carthage, Jasper Co. (1); Camden Co. (2); Benton Co.

(2); Galena, Stone Co. (7); Springfield, Greene Co. (3); Seligman, Barry Co. (Pils. & Fer.); Chadwick, Christian Co. (Pils. & Fer.); Marble Cave, Stone Co. (Pils. & Fer.); Cedar Gap, Wright Co. (Fer.).

From Macdonald county the shells are 10 mm. diameter; from Dade county only 9 mm. The body whorl is so constricted behind the peristome that the greatest diameter is not from a point on the lip, but on the whorl back of it.

103. Polygyra hirsuta Say.

Kansas City, Jackson Co. (4); River bluffs, Moniteau Co. (11); McAllister Springs, Saline Co. (16); Pettis Co. (16); Boonville, Cooper Co. (1); Columbia, Boone Co. (6); Jackson, Cape Girardeau Co. (1); Allanville, Same Co. (3); Scott Co. (?); Marble Hill, Bollinger Co. (1); Warsaw, Benton Co. (1); Fern Glen, St. Louis Co. (1); Jefferson City, Cole Co. (Walker Coll.); Callaway Co. (Greger); St. Louis Co. (1).

Postpliocene:—Providence, Boone Co. (3); St. Joseph, Buchanan Co. (1); Near St. Louis (Hambach).

Pilsbry says this has not been found south of Sedalia, Missouri, where I reported it some years ago. Jackson, and other places from which it is now reported are south of Sedalia, and the specimens are of this species; they certainly are neither *blandiana* nor *uncifera*. The shell from Jackson is more globose, of something more than five whorls, and the body whorl much more ventricose than in typical specimens. The striæ of increase are scarcely visible on the body whorl, but on the others show some bands of light color. The Allanville shells are larger than the Jackson.

104. Polygyra blandiana Pils.

Springfield, Greene Co. (6); Seligman, Barry Co.

The Springfield specimens were received from J. H. Ferriss. Pilsbry reports it from both the above localities.

105. Polygyra stenotrema Fer.

Douglas Co.

106. Polygyra monodon Rauck.

St. François Co. (1); Laclede Co. (2); Morgan Co. (1); Moniteau Co. (9); Sedalia, Pettis Co. (20); Boonville, Cooper Co. (11); Saline Co. (4); Clinton, Henry Co. (12); Warrensburg, Johnson Co. (8); Mound City, Holt Co. (10); Callaway Co. (6); Dade Co. (1); Lamar, Barton Co. (2); Monett, Barry Co. (10); Lawrence Co. (13); Jasper Co. (7); Camden Co. (3); Albany, Gentry Co. (Walker Coll.); St. Louis Co. (3); Gallatin, Daviess Co. (6).

Postpliocene:—Providence, Boone Co. (12); St. Joseph, Buchanan Co. (7); St. Louis (Hambach).

Those from Monett seemed to be imperforate, but on close examination a very small umbilical opening can be seen. The same is true of those from Callaway county. One shell from St. Louis county is very noticeable in having a very wide and prominent umbilicus, the peristome rounding to and connecting with the parietal tooth, and not entering into the umbilicus.

107. Polygyra fraterna Say.

Fern Glen, St. Louis Co. (1); Marble Hill, Bollinger Co. (1); Scott Co. (2); Camden Co. (1); Boonville, Cooper Co. (15); River bluffs, Moni-

teau Co. (11); Warsaw, Benton Co. (1); Pettis Co. (1); Columbia, Boone Co. (7); Birmingham, Clay Co. (13); Ste. Genevieve, Ste. Genevieve Co. (4); Taborville, St. Clair Co. (Walker Coll.); Milan, Sullivan Co. (Same); Clinton, Henry Co. (Same); Callaway Co. (Greger).

At Boonville some specimens were intermediate in size between *monodon* and *fraterna.* In Bollinger county the one specimen found was 9 mm. diameter, but from Scott county in the same part of the State they were only 7½ mm.

108. Polygyra fraterna alicia Pils.

Mineral Point, Washington Co. (1); Farmington, St. François Co. (3); Rivermines, Same Co. (6); Paris, Monroe Co. (6).

109. Polygyra fraterna friersoni Pils.

Jefferson City, Cole Co. (Walker Coll.).

110. Polygyra fraterna imperforata Pils.

Ste. Genevieve, Ste. Genevieve Co. (6); Cape Girardeau, Cape Girardeau Co. (1).

111. Polygyra dorfeuilliana Lea.

Fern Glen, St. Louis Co. (9); Hunter, Carter Co. (3); Howell Co. (3); Douglas Co. (2); Ironton, Iron Co. (1); Arcadia, Iron Co. (Baker); Stone Co. (Stearns); Neosho, Newton Co. (Walker Coll.); Pineville, Macdonald Co. (Walker Coll.); Cureall Springs, Howell Co. (Walker Coll.); Henry Co. (Pils. & Fer.); Callaway Co. (Greger).

112. Polygyra dorfeuilliana sampsoni Weth.

Warsaw, Benton Co. (25); Camden Co. (13); Barry Co. (13); Grand Falls, Jasper Co. (7);

Macdonald Co. (10); Springfield, Greene Co. (Pils. & Fer.); Chadwick, Christian Co. (P. & F.); Current river, Co. not given, (P. & F.); Seligman, Barry Co. (Pils.); Arcadia, Iron Co. (Baker).

These different lots vary somewhat in the distinctness of sculpture on the under side, in the size and position of the upper lip tooth, and in the flatness of the vault, but apparently not uniformly so or distinct enough to deserve a varietal name.

113. Polygyra jacksoni Bland.

Camden Co. (10); Dade Co. (10); Barry Co. (13); Ash Grove, Greene Co. (12); Grand Falls, Jasper Co. (1); Split Log, Macdonald Co. (1); Cassville, Barry Co. (1); Springfield, Greene Co. (P. & F.).

114. Polygyra triodontoides Bland.

Monett, Barry Co. (2).

Bulimulidæ.

bulimulus Leach.

115. Bulimulus dealbatus ozarkensis Pils. & Fer.

Cooper Co. (8); Camden Co. (5); Barry Co. (2); Macdonald Co. (5); Douglas Co. (2); Rivermines, St. François Co. (1); Oakwood, Marion Co. (2); Callaway Co. (Greger); Cass Co. (8).

Stearns reported *B. dealbatus* from Stone county. When I found this shell in Cooper county I thought that this was the most northern point in the State where it would be found, and I was much surprised afterwards to find it near Hannibal.

CIRCINARIIDÆ.

CIRCINARIA Beck.

116. CIRCINARIA CONCAVA Say.

Pettis Co. (2); Columbia, Boone Co. (6); Poplar Bluff, Butler Co. (3); St. François Co. (1); New Madrid, New Madrid Co. (1); Camden Co. (1); Scott Co. (1); Fern Glen, St. Louis Co. (7); Moniteau Co. (2); Macdonald Co. (4); Bear creek, Marion Co. (1); Galena, Stone Co. (1); Kansas City, Jackson Co. (1); Chadwick, Christian Co. (Pils. & Fer.); Callaway Co. (Greger).

Postpliocene:—Lupus, Moniteau Co. (6); Providence, Boone Co. (8); Near St. Louis (Hambach).

ZONITIDÆ.

ZONITINÆ.

OMPHALINA Rafinesque.

117. OMPHALINA FULIGINOSA Griff.

Scott Co. (4); Carthage, Jasper Co. (1); Jackson, Cape Girardeau Co. (1); Macdonald Co. (2); Seligman, Barry Co. (2); Warsaw, Benton Co. (2); Marble Hill, Bollinger Co. (1).

Pilsbry and Ferriss say that the early whorls of *fuliginosa* are invariably white, the cuticle being worn off. This is the case with all of the above except that from Marble Hill, but it is not full grown and is of only 3½ whorls. They describe a variety *fuliginosa ozarkensis,* which has fine spiral striæ, but none of the above show such lines.

118. OMPHALINA FRIABILIS W. G. B.

Cape Girardeau, Cape Girardeau Co.

These shells are of large size, up to 28 mm. diameter, and with apex entirely unworn.

VITREA Fitz.

119. VITREA INDENTATA Say.

New Madrid Co. (2); Cape Girardeau Co. (2); St. François Co. (14); Potosi, Washington Co. (3); Mineral Point, Same Co. (4); Howell Co. (1); Douglas Co. (4); Galena, Stone Co. (1); Laclede Co. (1); Mt. Vernon, Lawrence Co. (13); Peirce City, Same Co. (2); Greenfield, Dade Co. (15); Golden City, Barton Co. (7); Morgan Co. (2); Sedalia, Pettis Co. (20); Warrensburg, Johnson Co. (2); Jasper Co. (16); Camden Co. (23); Clinton, Henry Co. (5); River bluffs, Moniteau Co. (3); Split Log, Macdonald Co. (2); Moniteau Co. (5); Fern Glen, St. Louis Co. (1); Paris, Monroe Co. (1); Seligman, Barry Co. (Pilsbry); Arcadia, Iron Co. (Baker); Monett, Barry Co. (Pils. & Fer.); Chadwick, Christian Co. (Pils. & Fer.); Gallatin, Daviess Co. (2).

Postpliocene:—Below mouth of Platte river (Hambach).

120. VITREA HAMMONIS Strom.

Sedalia, Pettis Co. (46); Clinton, Henry Co. (4); Monett, Barry Co. (2); Columbia, Boone Co. (2); Seligman, Barry Co. (Pils.); Chadwick, Christian Co. (Pils. & Fer.).

121. VITREA SIMPSONI Pils.

Pilsbry and Ferriss identify a small race of the above at Chadwick, Christian county.

EUCONULUS Reinh.

122. EUCONULUS FULVUS Drap.

Sedalia, Pettis Co. (13); Lamar, Barton Co. (1); Dade Co. (1); Galena, Stone Co. (1); Golden City, Barton Co. (4).

ARIOPHANTINÆ Pils.

ZONITOIDES Lehmann.

123. ZONITOIDES ARBOREUS Say.

New Madrid, New Madrid Co. (1); St. François Co. (35); Jackson, Cape Girardeau Co. (25); Scott Co. (11); Poplar Bluff, Butler Co. (2); Bloomfield, Stoddard Co. (10); Galena, Stone Co. (4); Monett, Barry Co. (26); Springfield, Greene Co. (7); Douglas Co. (5); Lamar and Golden City, Barton Co. (34), (74); Jasper Co. (28); Aurora, Mt. Vernon & Peirce City, Lawrence Co. (15), (19), (1); Nevada, Vernon Co. (3); Warsaw, Benton Co. (1); Clinton, Henry Co. (89); Warrensburg, Johnson Co. (2); Saline Co. (5); Morgan Co. (3); Split Log, Macdonald Co. (5); California, Moniteau Co. (19); Chouteau Springs, Cooper Co. (26); Laclede Co. (9); Mound City, Holt Co. (18); Sedalia, Pettis Co. (74); Camden Co. (61); Greenfield, Dade Co. (2); Missouri river bluffs, Moniteau Co. (2); Ash Grove, Greene Co. (1); Grand Falls, Jasper Co. (2); Potosi, Washington Co. (9); Ironton, Iron Co. (2); Chadwick, Christian Co. (2); Callaway Co. (Greger).

Postpliocene:—St. Louis (Hambach).

PSEUDOHYALINA Morse.

124. ZONITOIDES MINUSCULUS Binn.

Sedalia, Pettis Co. (3); Clinton, Henry Co. (2); Warsaw, Benton Co. (3); Nevada, Vernon Co. (4); Jasper Co. (3); Lamar, Barton Co. (2); Douglas Co. (2); Mt. Vernon, Lawrence Co. (4); Potosi, Washington Co. (1).

GASTRODONTA Albers.

125. GASTRODONTA LIGERA Say.

Neeleyville, Butler Co. (4); New Madrid, New Madrid Co. (12); River bluffs, Moniteau Co. (7); Boonville, Cooper Co. (14); Sedalia, Pettis Co. (5); McAllister Springs, Saline Co. (5); Columbia, Boone Co. (9); Bear Creek, Marion Co. (5); Fern Glen, St. Louis Co. (3).

Postpliocene:—Providence, Boone Co. (1).

126. GASTRODONTA DEMISSA BRITTISI Pils.

Pilsbry and Ferriss doubtfully identify some specimens from Chadwick, Christian county with the above.

ENDODONTIDÆ Pilsbry.

ENDODONTINÆ.

PYRAMIDULA Fitzinger.

PATULA Hald.

127. PYRAMIDULA ALTERNATA Say.

Columbia, Boone Co. (25); Paris, Monroe Co. (15); Bear Creek, Marion Co. (1); Mound City, Holt Co. (2); Birmingham, Clay Co. (7); McAllister Springs, Saline Co. (11); Kansas City, Jackson Co. (5); Dade Co. (8); Pettis Co. (10); Morgan Co. (2); Golden City, Barton Co. (2); Carthage, Jasper Co. (6); Camden Co. (5); Jackson, Cape Girardeau Co. (5); Scott Co. (6); Marble Hill, Bollinger Co. (2); Madison Co. (7); Poplar Bluff, Butler Co. (7); St. François Co. (8); Allanville, Cape Girardeau Co. (17); Peirce City, Lawrence Co. (1); Arcadia, Iron Co. (Baker); North Jefferson, Callaway Co. (12); St. Louis Co. (2); Cooper Co. (4).

Postpliocene:—Providence, Boone Co. (17); Glasgow, Howard Co. (5); St. Joseph, Buchanan Co. (9); Bellevue (Hambach); Lexington (Hambach).

The collection has a sinistral shell from near Columbia, the first reverse land shell I have found in the State.

128. Pyramidula solitaria Say.

St. François Co. (3); Bollinger Co. (1); Fern Glen, St. Louis Co. (1); Morgan Co. (1); Camden Co. (6); Pettis Co. (6); River bluffs, Moniteau Co. (10); Columbia, Boone Co. (6); Bonne Terre, St. François Co. (Walker Coll.); Cooper Co. (Walker Coll.); Callaway Co. (Greger); Dent Co. (1); St. Charles Co. (5).

Postpliocene:—Providence, Boone Co. (22); Lupus, Moniteau Co. (8).

I have specimens from Indiana 28½ mm. diameter, while those from Pettis county are only 22.

gonyodiscus Fitz.

129. Pyramidula perspectiva Say.

St. François Co. (13); Madison Co. (1); Marble Hill, Bollinger Co. (12); Jackson, Cape Girardeau Co. (15); Poplar Bluff, Butler Co. (9); Benton, Scott Co. (9); Seligman, Barry Co. (8); River bluffs, Moniteau Co. (4); Cureall Springs, Howell Co. (Walker Coll.); Chadwick, Christian Co. (Pils. & Fer.).

Postpliocene:—Providence, Boone Co. (1).

helicodiscus Morse.

130. Helicodiscus lineatus Say.

Sedalia, Pettis Co. (20); Warsaw, Benton Co. (4); Nevada, Vernon Co. (2); Dade Co. (5);

Laclede Co. (3); Moniteau Co. (1); Douglas Co. (2); Golden City, Barton Co. (5); St. François Co. (8); Cassville, Barry Co. (1); Columbia, Boone Co. (1); Providence, Same Co. (100); Paris, Monroe Co. (5); Gallatin, Daviess Co. (2).

Postpliocene:—Mouth of Platte river (Hambach).

PUNCTINÆ.

PUNCTUM Morse.

131. PUNCTUM PYGMÆUM Drap.

Providence, Boone Co. (4).

132. POLYGYRA ANDREWSI W. G. B.

St. François Co.

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Issued July 18, 1913.

Transactions of The Academy of Science of St. Louis.

VOL. XXII. No. 4.

VARIATIONS IN THE EARTH'S MAGNETIC FIELD.

FRANCIS E. NIPHER.

Issued November 3, 1913.

VARIATIONS IN THE EARTH'S MAGNETIC FIELD.*

Francis E. Nipher.

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On account of the possibility of local disturbance due to street cars, it was thought desirable to repeat some of the work described in a former paper in these Transactions, No. 2, Vol. XXII. This was done during the summer of 1913 in a large tent 18x20 ft. located on the lake shore at the north end of Lake Huron. The station was about 50 ft. from the lake and about half a mile N. W. of the village of Hessel, in Mackinac County.

The magnetic needle was a piece of knitting wire 7 cm. in length, suspended upon a fiber of unspun silk about 40 cm. in length. The enclosing case was formed from a large glass bottle, the top of which was removed. A metal cap fitting closely around the top of the glass jar thus formed, was provided with a vertical brass tube, having at its top a torsion head and means for attaching the suspension fiber. This metal cap was sealed to the glass jar by means of adhesive rubber tape. The jar was mounted in a closely fitting base provided with leveling screws, which were about 30 cm. apart, in order to secure stability. A fine copper wire soldered to the middle of the needle, served as a means for attaching the suspension fiber. It also extended below the needle, and to its lower end was attached a horizontal wire about 6 cm. in length, which dipped into coal oil in the bottom of the jar, and served as a damper for the needle. Attached to the wire suspension of the needle was a small mirror, by means of which the motion of the needle was observed, in the usual way with a tele-

*Presented before The Academy of Science of St. Louis, October 20, 1913.

scope and scale. The scale was divided into centimeters and tenths. The scale value was 1 *mm*=3.37 minutes of deflection of the needle.

The structure upon which the needle and telescope were mounted, was a frame constructed of 2x4 inch timber bolted together with brass bolts, and the legs or corner posts of the frame extended two feet down into clay and gravel soil. The structure was braced longitudinally and transversely, the braces being held in place by large brass screws. The structure thus formed was 8 ft. in length in a north and south direction with respect to the magnetic meridian, and 4 ft. in width.

The needle was deflected 90° from the magnetic meridian, by means of two bar magnets 2 ft. in length whose axes made an angle of 45° with the meridian. The resultant field was thus the same as the horizontal component of the earth's field. This resultant field was then partly compensated by two bar magnets 4 ft. in length, on either side of the needle, and at the ends of the table, about 4 ft. distant from the needle. The final resultant field in which the needle was thus placed was about 0.05 that of the horizontal component of the earth's field. This was determined by the oscillation method, before the damping liquid was introduced. The time of vibration was corrected for the torsional effect of the suspension fiber.

With this arrangement, the needle is very sensitive to changes in the horizontal component of the earth's field, and it has the advantage of permitting these changes to be observed at any instant. Some preliminary observations were made with the control magnets exposed to the air. The tent was provided with a fly, which permitted a free circulation of air between it and the roof. It however became evident that the variation in position of the needle was materially influenced by a variation in the temperature of the magnets, although the maximum temperature of the day during July and August did not exceed 85° F. This temperature effect was

greatly reduced by wrapping the magnets in heavy padded blankets. It was, however, soon eliminated by maintaining all of the control magnets at a temperature of 32° F. This was done by placing each magnet within a piece of heavy rubber tubing. This tubing was of strong fiber, coated within and without with rubber. The ends were plugged and sealed with wax. The tubes with the enclosed magnets were mounted in V-shaped supports within boxes put together by means of copper nails, and calked. The boxes were then filled with fragments of ice, packed closely around the rubber tubes. The ends of the boxes rested on the side timbers of the frame so that the blankets could be wrapped around the boxes. The boxes were provided with outflow tubes of brass.

The maintaining of the control magnets at a fixed temperature, diminished the daily swing of the magnetic needle in a very appreciable degree. It did not apparently affect the character of the changes due to wind-gusts and cloud shadows. It did, however, serve to remove all possible doubt from the conclusions. In this series of observations, it was not the object to make precise measurements of the quantities involved. It was a search for fundamental phenomena. For precise measurements the two sets of magnets might each be replaced by two coils as in the Helmholtz-Gaugain galvanometer. These might be mounted on a table capable of rotating around a vertical axis coincident with the suspension fiber. Two telescopes with scale mounted 90° apart upon the table would serve to properly adjust the table when both circuits were open, and to deflect the needle 90°. The current in the deflecting coils would be increased until the telescope with axis east and west is directed upon the reading corresponding to the magnetic axis of the needle, as determined by the other telescope, the torsion head being turned 90°.

The current and the constant for the coils being known, the value of H is determined at that instant. The resultant field could then be decreased to any desired

amount by closing the circuit containing the compensating coils, and varying the current by means of a proper resistance (carbon plates with a compression screw).

It was of course found that in general the intensity H of the horizontal component of the earth's field, increases during the day, reaching a maximum late in the afternoon. The numerical value of H is, however, greater on clear days than on cloudy days. On days which are clear in the forenoon and cloudy in the afternoon, the maximum may occur in the middle of the day, or before noon. During days when the air is quiet, the needle is more quiet during cloudy or clear days, than when the sky is covered with small clouds with blue sky between.

On days when the wind blows in gusts at intervals of one or two minutes the needle is more unsteady in its movements, than on quiet days, or on days when the wind is more uniform.

On days when gusts of wind are frequent, it is impossible to identify any particular wind-gust with any particular disturbance of the needle. The reason for this appears to be explained by an observation made on July 14. During the forenoon of that day the wind was very mild from the west. Shortly before 1 o'clock the wind suddenly changed to the south, while it continued at the rate of 3 to 4 miles per hour. At 1:10 p. m. the needle began to vibrate to and fro. The scale reading at each extreme position was recorded. This was continued for nine minutes, when a blast of wind came in from the lake to the south. It overturned a sail boat lying at a dock about 200 ft. distant, the sails of which had been raised in order to dry them. It was by far the most violent wind of the summer. About eight minutes later the wind had practically ceased, and the vibrations of the needle had also ceased. The scale reading had been under constant observation before the gust of wind began. The reading was recorded each minute, and even more frequently during times of mild disturbance, when slow to and fro movements made this necessary. When

the movement was apparently uniform in one direction, records were made at intervals of five or ten minutes, although the needle was under almost constant observation.

During the oscillations above referred to, the watch reading was taken at as frequent intervals as was possible. In these oscillations the time of one to and fro vibration was about 50 seconds, as nearly as it could be determined. The time covered by consecutive vibrations frequently varied so greatly on other occasions that no precise value could be given for the time of vibration. The effect of the damping liquid was such that the needle would come practically to rest in three or four semi-vibrations when deflected 90°.

These vibrations above described are graphically shown in Plate XXI. The instant when the blast of wind reached the observing station is indicated by the arrow, located near the middle of the group of vibrations representing this local magnetic storm. The ordinates are in scale divisions. The greatest amplitude of swing was about 20 scale divisions. The hour of the day is laid off upon the horizontal axis. The fact that the needle was affected by this air disturbance south of the station at least nine minutes before it reached the station, is in exact harmony with the suggestion given in the former paper in these Transactions referred to above. As was there pointed out, a brush which disturbs iron filings at any point on a plate of glass above a bar magnet, is producing an ether disturbance in the field of that magnet. This observation also shows clearly, why it is that on stormy days, when gusts of wind follow each other at frequent intervals, the effect due to any one gust cannot be identified. At any instant, the needle responds to a summation of these disturbances.

It could hardly be expected that such a wind disturbance could produce a magnetic storm of more than a local character. But it is not at all improbable that tor-

nadoes and tropical cyclones may produce much more wide-spread effects. A wind disturbance among the atmospheric ions which sometimes accumulate along the magnetic lines of force at the earth's magnetic poles, might be expected to produce the effects which have long been observed.

On ten or twelve occasions similar effects were observed, which were caused by a local dash of rain. When rain falls continuously or at intervals during a day when the sky is covered with clouds, which extend over adjoining states, the needle shows no appreciable disturbance. The horizontal component of the earth's field is then much weaker than it would be if the sky were clear, but there is no additional change due to a rainfall. The limiting condition has been already reached.

When small clouds are scattered over the sky and a local fall of rain occurs at the observing station, the sunlight passing through the air through which the raindrops fall, a very marked magnetic storm is produced. Such a disturbance is represented in Plate XXII.

This rain, which was very violent, began while I was at the noon-day meal. It lasted about ten minutes. When the tent was reached the rain had practically ceased at the station. The sun was visible during most of the time while the rain was falling. The area covered by the rain was probably not over one or two square miles. Its boundary could be seen upon the lake to the south, while I was on the way to the tent. The needle showed that we were then in the midst of one of the most violent magnetic storms of the summer. The vibrations ceased about five minutes after observation began. The extreme reading of the scale for each oscillation was taken. They are represented in Plate XXII, together with subsequent readings of the needle represented on the same time scale. Readings made before leaving the tent for lunch are also shown. The gap between the readings before and after lunch is only in part represented, as is indicated by the figures at the bottom of the

plate representing the hour of the day. The needle was in a more disturbed condition after the vibrations had ceased than it had been before. Evidently the rain had some effect upon the magnetic field at the station when it was falling through air to the south of the station, and had ceased at the station. The needle was damped during this day, so that summation effects were impossible, nevertheless in one of these oscillations the needle vibrated through an arc of over 5°.

This rain occurred on August 26. A diagram representing the movement of the needle between 10 a. m. and sunset, is presented in Plate XXIII. The vibrations due to the rain occurred at the close of the first gap in that curve. They cannot be properly represented here with the time-scale used in this plate. They are replaced by a straight line. The second gap in the diagram represents the time required to finish the noon-day meal, which had been interrupted by the rain. The part of the diagram of Plate XXII, after the hour of 1:05, is the part which in Plate XXIII lies between the two gaps.

Plate XXIII also represents the effect upon the horizontal component of the earth's field, of two large dense and sharply defined clouds passing over the sun. Their effect is shown at points corresponding to 11:10 a. m. and 4:28 p. m. During seven weeks the needle had been under constant observation, from sunrise to sunset, in order to secure the results which were here obtained. On many days evidence of cloud effects were observed which seemed conclusive, but usually the edges of the cloud would not be sharply defined. In some cases the edges would be more or less transparent, in some cases small clouds of irregular form would surround the larger cloud. It often happened that large dense clouds appeared to be approaching the sun, and the needle gave results which were wholly different from those which had been expected. On going out of the tent it would be found that the cloud had behaved in a wholly different manner from what had been expected. In some cases it

practically disappeared before it reached the sun. Sometimes it was dispersed into smaller clouds, which were more or less hazy in outline. Their effect might be appreciable and persuasive, and yet more or less unsatisfactory.

The fact that it was impossible to predict at what moment the desired conditions might present themselves, and the necessity for having a record of the behavior of the needle for a considerable time interval before the sun entered a dense cloud, made it necessary to keep the needle under constant observation, recording the results during each minute of the day, sometimes at lesser intervals, so far as this was possible. The only interruption to this work during July and August was from August 12th to 16th, during which interval a severe attack of a painful illness made work of any kind impossible.

The sun entered the well defined edge of the first cloud above referred to at 10:45 a. m. The needle had been previously moving continuously in a direction such as would be caused by a steady increase in the strength of the field. When the sun entered the cloud, irregularities in the movement of the needle were observed. The air on the border of a cloud shadow often gave evidence of a disturbed condition. In this case the sun was in the center of the cloud at about 11:10 a. m. This cloud then covered the overhead sky down to about 45° from the horizon. Below this cloud the sky was clear. The sun reappeared at 11h 12m 30 sec. At this time the scale reading corresponded to the minimum shown in the diagram, Plate XXIII. The needle at once reversed its direction of movement. The reading at 11:40 or 11:50 was, as the diagram shows, about what it would have been if the cloud had not appeared.

This cloud was soon afterwards broken up into smaller clouds, and other smaller clouds appeared. From 12:30 to 2 p. m. the sky was partly covered here and there by smaller clouds, so that at the station, as at surround-

ing points, the sun was visible at and during frequent intervals. One of these small clouds unexpectedly gave rise to the dash of rain before discussed. The general effect of these clouds is shown in the general drop in the curve between 12:30 and 1:30 p. m.

The sun entered another dense and sharply defined cloud surrounded by clear sky, at 4:20 p. m. of this same day, after the daily maximum had been passed. It emerged from this cloud at 4:28 p. m. While the sun was hidden by this cloud, the intensity of the magnetic field diminished as in the other case, as is shown by the drop in the curve. When the sun reappeared the intensity at once began to increase. At 4:37 the reading was that corresponding to the general trend of the curve during that afternoon. The time of entering and leaving the cloud is in both cases indicated on the diagram by arrows.

It would thus appear that cloud shadows during the day have the same effect upon the earth's magnetic field that the earth's shadow has at night. The lines of the field sway around them. They sway above the clouds into the sunlight. The horizontal component would thus be diminished below the clouds.[1]

It is impossible to present here the full evidence obtained, which to me seems to establish beyond all question the conclusion that local variations in the earth's magnetic field are determined wholly by local weather conditions. It is contained in 300 pages of closely written notes on pages 8 inches square. While it might at first seem that the greater part of this record was of no importance, it does establish the general conclusion that when local conditions were uniform, whatever they might be, the magnetic needle showed no marked disturbance of an abrupt character, such as we have in these vibrations.

[1] Observations of the character here discussed should be made during solar eclipses.

It may suffice to discuss briefly the record of July 19. In doing this the weather maps kindly furnished by the Weather Bureau at Washington were of material assistance. On the afternoon of this day, the needle showed more disturbance than on any other day. At 10 a. m. a rain cloud was observed in the southern horizon. At 11:45 the needle began to vibrate, the average amplitude of vibration being about 20 scale divisions, and sometimes reaching 35. The wind, which had been from the northwest, had changed to the south. This continued until about 12:10 p. m., when the needle became less disturbed, and observations ceased until 12:45 p. m. During this disturbance, it could be seen that a rain was falling on the lake to the south. At 12:45 a violent dash of rain began, which continued for ten minutes, and then continued as a milder rain until 1:05. The clouds were not continuous over the sky. The sun appeared at intervals.

The point of importance is that these vibrations began and continued for an hour, while a rainstorm existed to the south of the station, and before rain began to fall at the station. During the remainder of the afternoon periods of sunshine and rain came in alternation. Between 2:37 and 3:10 over half an inch of rain fell, from what appeared to be a local cloud. The needle continued to vibrate during this rain, and after it had ceased at the station and while its roar could be heard upon the lake to the south. The wind was very mild during the entire day, its velocity not at any time exceeding 8 or 10 miles per hour. The amplitude of the vibrations sometimes reached 40 scale divisions. The greatest amplitude of the day was 49 scale divisions. The needle was damped during this day.

The data given on the weather map show that the rain which visited the observing station extended from Escambia, which is in northern Michigan, near the north end of Lake Michigan, to Alpena, which is in southern Michigan, near the north end of Lake

Huron. At the former station the rainfall was 0.44 inch and at the latter it was 0.36 inch. At Saginaw, Mich., which is south of Alpena and also on the west side of Lake Huron, the rainfall was 0.26 inch. At Sault Ste. Marie, at the outlet of Lake Superior, no rain fell. This rainstorm was a purely local one, extending across the head of Lake Michigan and along the straits of Mackinac, and probably into Lake Huron.

On July 16, 26, 27 and 31 similar local rains occurred in the same region during the midday hours. In some cases there was practically no rainfall at Hessel, but the clouds which were observed near the horizon were recognized as rain clouds. The weather maps show that rain fell at surrounding weather stations. On all of these days, the needle was in to-and-fro vibration at intervals during the day. In all cases when the weather maps show rains in this region, which occurred during the hours of observation of the needle, the needle showed such vibrations.

On three days they were observed when violent gusts of wind occurred at the station, with no rain in that part of the country.

On August 23, very marked and sudden changes in the position of the needle were observed, and they were so unusual as to lead to the suspicion that something unusual must have happened. There were no vibrations accompanying those disturbances. The day was unusually clear. Very light rains occurred at all of the nearest weather stations, the greatest fall, 0.20 inch, being at Houghton, about 200 miles distant in a direction a little north of west.

On August 8, a violent rain accompanied by a continuous roar of overhead thunder occurred between 4 and 6:30 a. m. The needle was then very quiet, as was the case on every morning of the summer with one exception. On this morning when a few oscillations occurred after sunrise, they were accompanied by violent gusts of wind.

On two or three occasions phenomena were observed which suggested that winds from the north, reaching the station through a grove of trees, had a slightly different effect from that of a wind from the lake. This subject requires additional attention.

Perhaps the most interesting phenomenon observed during the summer was the continuous vibration of the needle during a period varying from half an hour to two hours preceding sunset. This was observed on nearly every evening when the western sky was clear. The vibrations were greatest when the day had been clear, and the intensity of the field had reached a high maximum. They did not occur when the afternoon sky was covered with a dense cloud. The cloud shadow is then joined to the earth's shadow. They did not occur in the morning, either before or after sunrise. Observations were sometimes begun as early as 2 o'clock a. m. They were usually begun about an hour before sunrise.

Plate XXIV, made from observations on August 31, gives an illustration of these sunset disturbances. The plate shows how the needle moved during the afternoon, before the oscillations suddenly began. In the original drawing, this part of the curve was drawn to a time scale of 6 cm. per hour. For the period during which the oscillations are represented, the time scale is 6 cm. to about 3 minutes. One to and fro oscillation was drawn to each half-centimeter. During this day the damping liquid had been removed. It will be observed that the disturbing cause ceased at about 5:45 and the needle gradually came to rest. On this day two similar violent disturbances occurred subsequently before sunset, which are not represented in Plate XXIV. The greatest amplitude reached was about 250 scale divisions, or about 14° of arc. The extreme scale reading for each and every vibration was read.

In nearly all of the observations on this sunset disturbance, the motion of the needle was restrained by the damping fluid. The amplitude of the vibrations was

then in general over an angle not exceeding 50 scale divisions or 2.8 degrees. The time of vibration was practically the same whether the damping fluid was used or not. It was not uniform in either case. The vibration of the damped needle frequently continued without cessation for an hour or more. At this hour of the evening there was usually no wind at the station.

It is evident that along what may be called the sunset meridian, there will generally be places where cloud shadows are joined to the earth's shadow. Since only the horizontal component of the earth's field of force is effective in action upon the needle, we may consider the conditions which would exist in a field of force in which the lines are horizontal. Where the clouds occur, these lines tend to sway above the clouds into the sunlight. If we consider these lines to behave like elastic threads, they are elongated by this distortion. They snap asunder and disappear as they are thus distorted and forced towards the approaching shadow of the earth, the field diminishing in strength in a rhythmical way. This statement must be considered as figurative in character, but it is in a certain sense descriptive of the observed phenomena. It is with some surprise that I find that this sunset disturbance has not been observed at stations where continuous records are made. This conclusion obtained from an examination recently made of government publications has been confirmed by information just received from the chief of the U. S. Coast and Geodetic Survey. Evidently the subject deserves additional attention.

It will of course be understood that the fact that wind-gusts a few miles distant are found to affect a magnetic needle, is in harmony with the well-known fact that solar disturbances also affect it.

The observation of Young at Sherman, Idaho, on August 3, 1872, showed that a solar outburst produces electromagnetic waves, which travel with the velocity of

light.[2] The effect on the magnetic needle at Greenwich and Stonyhurst was recorded at the same instant, that a solar disturbance was observed by Young (within the instrumental errors). Such results should lead us to expect that wind-gusts in air ionized by sunlight or by solar dust, as has been pointed out by Arrhenius, should produce similar results of a more local character.

In 1823, Barlow[3] made an experimental study of the diurnal variation of the earth's magnetic field. He deflected the needle into an east and west position, by means of two control magnets, lying in the magnetic meridian, acting upon opposite ends of the needle. At his request, his associate, Christie, continued the work. The effect of the earth's field was in part compensated by a magnet parallel to the dip needle. Their papers are in sequence in the Phil. Trans. of the Royal Society for 1823. Barlow gives his conclusion as follows:

"It appears to me that the quantity of daily change depends in a greater degree on the intensity of the solar light, than on the mere temperature of the day, although it is certain from some recent experiments of Mr. Christie, that the change of temperature of the air during the day, has a much greater effect upon the intensity of the opposing magnets than I could possibly have imagined."

Christie varied the temperature of the control magnets by placing upon them paper moistened with cold and with hot water. He concluded from the effect thus produced upon the magnets, that temperature, if not the only cause, is the principal cause of the daily variation in the earth's field.

A part of the work of both Barlow and Christie was done in their gardens, and the remainder in their houses,

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[2] The Sun. By Young, p. 158.

[3] Barlow should not be forgotten. He was the first to make an electric motor. Barlow's wheel is the rotating armature of an electric motor. Eight years later Faraday reversed this toy motor, and produced the first electrical generator. Neither of these men realized what he had accomplished.

which were about a mile apart. Both found great differences in the daily variation indoors and in open air, and various possible causes for it are discussed. Barlow concludes that it is probably due to the cause discovered by Christie, that the intensity at any point in the field of a bar magnet depends upon the temperature of that magnet. He ascribes this difference to the different temperature conditions of the control magnets. Nevertheless he is of the opinion that the quantity of daily change in the earth's field depends in a greater degree upon the intensity of solar light, than upon the mere temperature of the day. Evidently his intuitive faculty was of a high order.

Barlow's conclusion did not carry with it any rational explanation of causes, since at that time ionization of the air, by sunlight, resulting in an increase of its permeability, was unknown. The work of Christie also raised a doubt in the minds of others. Subsequent writers seem to have found it necessary to say that the daily variation and local magnetic storms had not been satisfactorily explained.

During the last fifteen years the present writer has made various attempts to produce a local magnetic storm in the earth's field by means of small amounts of high power explosives. The results discussed in the present paper seem to indicate beyond question that such explosions are capable of producing magnetic disturbances. The effect of the gust of wind shown in Plate XXI was to produce an ether disturbance extending far beyond and in advance of any air waves, or air disturbance.

Recent experiments with dynamite on the grounds adjoining the buildings of Washington University have not given conclusive results. It is difficult to eliminate other disturbances, and it is not permissible to use as large a quantity of the explosive as will probably be necessary. It is hoped that this work may be continued at Hessel during the coming summer.

Correction.—In Vol. XXII, No. 2, p. 59, line 1 from the top, erase *the* before Ampère.

EXPLANATION OF THE PLATES.

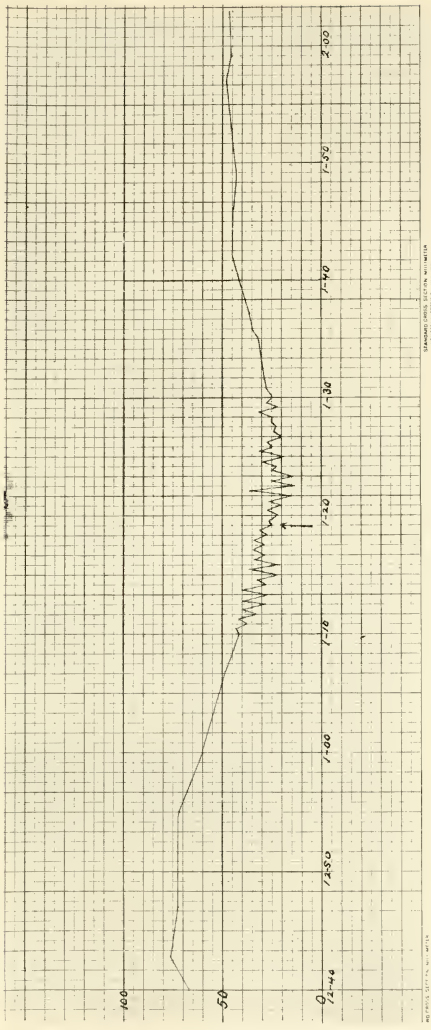
Plate XXI.—A local magnetic storm due to a local gust of wind of very unusual severity, lasting ten minutes, on a calm day. The wind storm reached the station nine minutes after the magnetic disturbance began, the time being indicated by the arrow.

Plate XXII.—A local magnetic storm due to a violent and very local fall of rain.

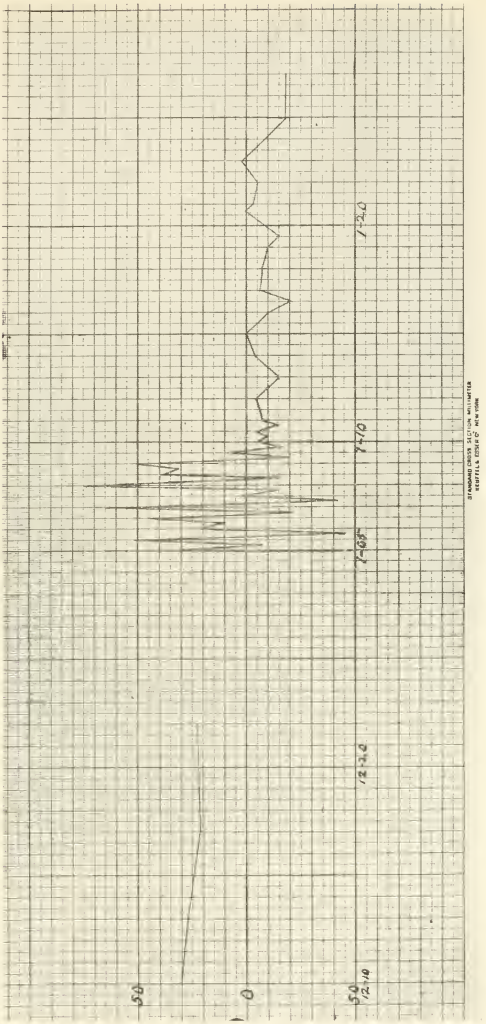
Plate XXIII.—A decrease in the horizontal intensity of the earth's magnetic field, due to two dense clouds surrounded by clear sky, passing over the sun, shown on the diagram at 11 a. m. and 4:30 p. m.

Plate XXIV.—A magnetic storm such as was observed usually on clear days shortly before sunset.

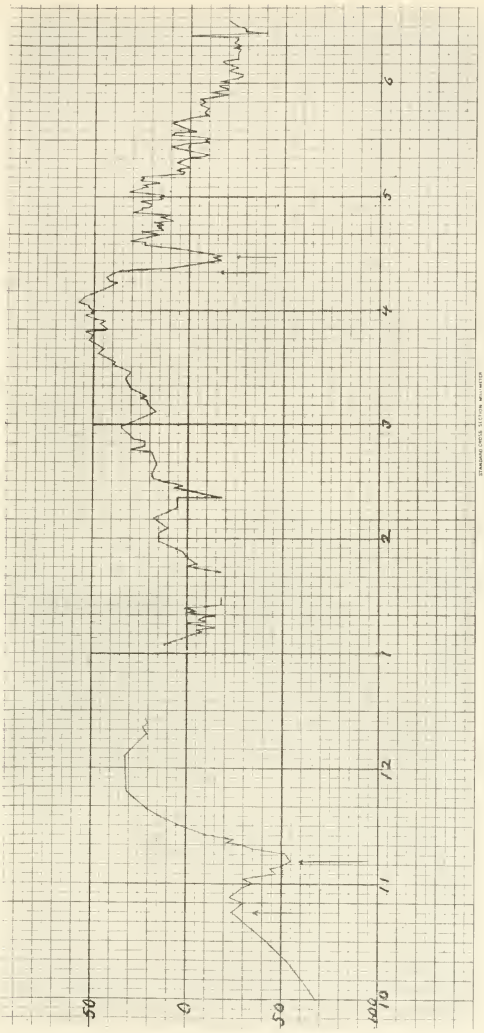
Issued October 3, 1913.



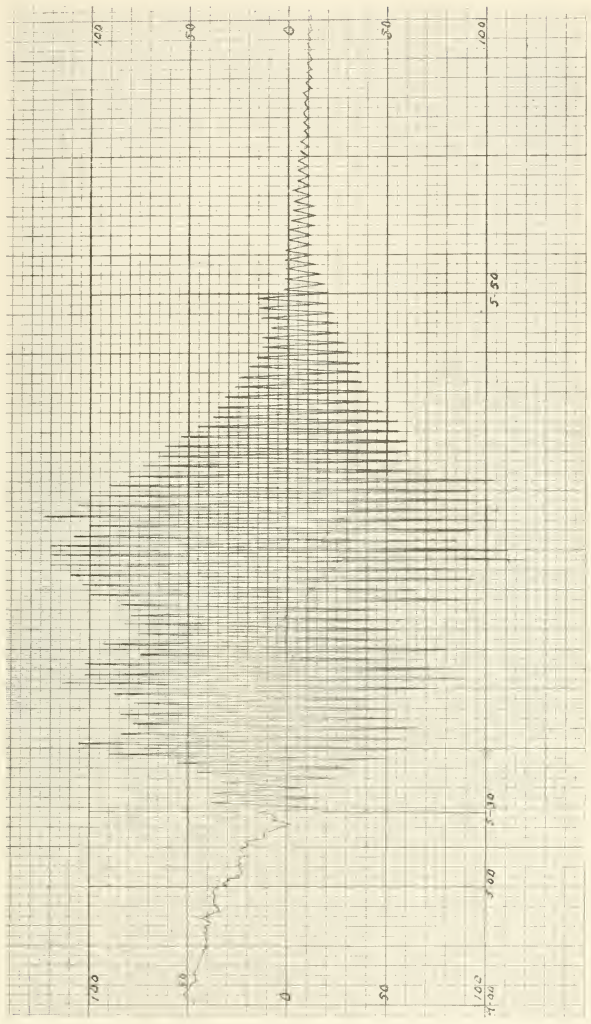
MAGNETIC STORM DUE TO WIND.



MAGNETIC STORM DUE TO RAIN.



EFFECT OF CLOUD SHADOWS.



MAGNETIC STORM AT SUNSET.

Transactions of The Academy of Science of St. Louis.

VOL. XXII. No. 5.

THE FLOWERS OF DIOSPYROS KAKI L. F.

H. HAROLD HUME.

Issued December 31, 1913.

THE FLOWERS OF DIOSPYROS KAKI L. F.*

H. Harold Hume.

To quote from the usual descriptions of the genus *Diospyros* as given in American texts, the flowers are "dioecious, rarely polygamous" and though both staminate and pistillate flowers are accurately described, no mention is made of the characteristics or peculiarities of the perfect flowers, though the persimmon has three kinds of flowers, namely, perfect, staminate and pistillate. This naturally leads to the belief that the perfect flowers are indeed rare in the American species, *D. virginiana* and *D. texana.* A careful examination of many trees of the former species, while in bloom, has resulted in finding none so far and difficult as it would be to find such flowers on growing trees, it would be almost as difficult to detect their presence in herbarium specimens. Perhaps the easiest way to find them would be to locate, if possible, staminate trees which bear some fruit. A careful search of such trees during the next season might lead to their discovery. However the perfect flowers of an introduced species, *D. Kaki* have been found as detailed below.

On April 19, 1909, while pollenating flowers of *D. Kaki* with pollen of *D. virginiana,* staminate flowers of *D. Kaki* were first noticed on a tree of "Taber's No. 23" planted March 4, 1899. As the blooming period for this particular tree was nearly over, only six staminate flowers could be found, but a careful examination of the dried corollas on the ground beneath the tree showed that hundreds of these flowers had been produced, and in the tree, numerous small twigs were found with the peduncles of staminate flowers still adhering. Pistillate

* Presented by title to The Academy of Science of St. Louis, November 17, 1913.

NOV 13 1914

flowers were also borne in large numbers and, as expected, the tree set a very heavy crop of fruit.

A note calling attention to these flowers and their possible value was published in *Science*.[1] The only certain reference to the staminate flowers of *D. Kaki* in American literature previous to this, by one acquainted with them, is by Berckmans,[2] who mentioned the occurrence of staminate flowers on young trees, but did not describe them and apparently attached no importance to their presence. Watts[3] may have seen them, but he leaves us in doubt. In describing the flowers of *D. Kaki* he says, "The flowers are inconspicuous, whitish green; the peduncles are usually three flowered. The flowers are complete, but all varieties are not equally self fertile." He makes no mention of the pistillate flowers, which are produced singly, and if by complete he meant that the flowers contained pistils and pollen bearing stamens, his observation was unusual, for perfect flowers are very scarce.

In European literature, the staminate flowers are described by Hiern,[4] Naudin[5] and Carriere[6] and mentioned by other writers.

In the spring of 1910, though a thorough examination of the same tree of "Taber's No. 23" was made, not a single staminate flower could be found. On younger trees of the same and of other varieties, however, they were found. The examination of trees, while in bloom, was continued through the blooming seasons of 1911, 1912,

[1] Hume, H. Harold. Non-fruiting of Japan Persimmons due to lack of Pollen. Science, N. S., Vol. XXX., No. 766, Sept. 3, p. 308-309. 1909.

[2] Berckmans, P. J. Persimmons. Cyclopedia American Horticulture, 3: 1281. 1901.

[3] Watts, R. L. Persimmons, University of Tennessee Agr. Exp. Station, Bulletin, Vol. XI., No. 1, Apr., p. 204. 1899.

[4] Hiern, W. P. A monograph of Ebenaceae. Transactions Cambridge Philosophical Society XII, Part 1, p. 227. 1872.

[5] Naudin, M. Ch. Quelques Remarques an sujet des Plaqueminiers (*Diospyros*) cultives a l' air libre dans les Jardins de L'Europe. Nouvelles archives du museum D' Histoire Naturelle 2" ser 3. 224. 1880.

[6] Carriere, E. A. Revue Horticole. 253-258, Plate, p. 254. 1872.

1913, with the result that staminate flowers have been discovered on several horticultural varieties, such as "Taber's No. 23," "Taber's No. 129," "Okame," "Masugata," "Siang" (S. P. I. 21910), "New Sien" (S. P. I. 22368), S. P. I. No. 27037 and an unknown variety found near Eagle Lake, Fla., which will be referred to as the Eagle Lake tree. On some of these varieties the appearance of staminate flowers is sporadic and influenced by unknown causes, while on other varieties they appear as regularly as the trees bloom.

So far as can be determined no mention has been made in either American or European literature of the occurrence of perfect flowers on *D. Kaki.* They are doubtless rare and our own observations are in accord with this belief. Perfect flowers were discovered in April, 1910, on three, different, two-year-old, "Okame" trees and on two trees of "Taber's No. 23" of the same age. In April, 1913, they were found on four-year-old trees of "Siang," and "Taber's No. 129" and on two-year-old trees propagated from the Eagle Lake tree. They are so different from either the staminate or pistillate flowers that when once known, they may be readily recognized by their external characters.

Location of Flowering Twigs.

All three types of flowers, of *D. Kaki,* are borne on shoots of the current season's growth and open shortly after the shoots and leaves are developed. In North Florida the blooming period usually occurs during the first three weeks in April. In some seasons it may begin as early as March 26th and it sometimes ends as late as May 7th. Delayed blooms may occasionally be found even at later dates.

The staminate flowers are usually borne on small, rather weak shoots which develop from lateral buds on last year's branches. On the strong vigorous twigs which develop from the buds at or near the end of the same branches, the pistillate flowers of the same trees

are usually borne. Sometimes, however, the two kinds of flowers occupy adjoining axils on the same twig. Occasionally the staminate flowers are found on vigorous twigs, particularly if pistillate flowers are entirely absent on shoots of a given branch. On "Taber's No. 129," the staminate flowers sometimes occupy the terminal shoots, and the pistillate, the lateral ones, especially if they are equally or nearly equally vigorous. The rule, however, is as already stated. The few staminate flowers so far found on "Okame" were all on short lateral twigs, and the same is true of the many flowers found on "Siang" (No. 21910). On "Masugata," "Taber's No. 129" and the Eagle Lake tree they are more frequently to be found on the vigorous twigs to which reference is made above.

Perfect flowers are usually associated with the staminate ones. Up to this time, they have not been discovered on any varieties of the fixed pistillate flowering type. In other words, it appears that the perfect flowers are a development from the staminate form and not from the pistillate form. When present, they are found more usually near the base of the strong and vigorous twigs which occasionally bear staminate flowers than on the short and comparatively weak lateral twigs on which the staminate flowers are generally found. Their development from the staminate form appears to be connected with the food supply.

Staminate Flowers.

Sometimes staminate flowers are produced in great profusion. They are borne normally in 3-flowered cymes in the axils of the bract-like leaves and normal leaves at the base of the twigs. Sometimes they appear at the very base of the twigs from flower buds located beneath the persistent scales of the last year's growth and occasionally on many flowered branches they are produced from last season's buds without apparent branch formation. Occasionally the cymes are four-flowered, some-

times two and at other times the flowers are produced singly. Particularly is this last true of the flowers at the very base of the twigs and also of those flowers which are sometimes located on pistillate flowering twigs.

The peduncles are 6 to 10 mm. long, slightly hairy, slender, curved downward, the secondary pedicels axillary in the axils of small linear early caducous bracts which are found on the main peduncle. These bracts are usually shed before the center flower of the cyme opens. The calyx is light green, sparsely hairy, four lobed, the lobes ¼ to ½ the length of the corolla-tube, thin, rounded at the points. The corolla is 9-14 mm. in length, light yellow, constricted beneath the reflexed lobes. These lobes are deep yellow and velvety on the upper surface, with margins minutely and sparsely hairy. If the ovary is entirely lacking the base of the corolla is closed and slightly pointed, but if the ovary is rudimentary and of some size, the base is open. The stamens are inserted on the corolla in two or three rows, 16 to 24 in number, the outer row or rows longer, the upper end of the anthers of the longer stamens reaching to and filling the throat of the corolla, anthers much longer than the very short hairy filaments. Pollen is produced abundantly and after being shed from the longitudinal slits in the anthers, it is held on the inner surface of the corolla in considerable quantities.

Occasionally a staminate and a perfect flower are found attached to the same peduncle, and sometimes a staminate flower is developed in one of the bracts on the pedicel of a pistillate flower.

The staminate flowers of "Okame" are not so pointed as are those of other varieties. The throat also is larger.

When the number of stamens is more than sixteen and less than twenty-four, the third or inner row of smaller stamens is only partially complete.

The peduncles of the staminate flowers are persistent through the summer and winter following the spring when they developed and are a satisfactory means of

determining whether a given tree produced staminate flowers.

Pistillate Flowers.

The pistillate flowers are solitary in the axils of the bract-like leaves and normal leaves near the base of the twigs. The flowers of "Tanenashi," "Okame," and "Tsuru" are very frequently found in the axils of the bract-like leaves, while the flowers of "Triumph," "Zengi" and "Costata," for example, are generally found in the axils of true leaves. Pedicels 14 to 32 mm. long, covered with minute hairs, curved so as to turn the opened flower downward, provided with two caducous bracts which are 2-3 mm. wide by 8-15 mm. long. The calyx is four parted, large, foliaceous, 25-35 mm. across the expanded lobes. The lobes are pointed or rounded, flattened or with margins reflexed, giving the lobes a more pointed appearance, nearly twice the length of the expanded corolla, outer surface minutely hairy; upper surface of calyx, close to and beneath the ovary covered with a dense hairy cushion. The corolla is 4 parted, light yellow, 10-17 mm. long, quadrangular with blunt angles, lobes reflexed light yellow on inner surface, constricted below the lobes, the throat usually somewhat quadrangular, margins of lobes minutely ciliate. The stamens are 8 in number clothed with fine white hairs, the pointed, abortive anthers curved inward over the ovary, filaments nearly as long as the anthers; ovary finally 8-celled, flattened, rounded or pointed, style sparsely hairy at the base, four parted upward; stigma much branched.

The stoutest pedicels observed are those of the variety "Zengi," 3-4 mm. in diameter; "Tsuru" has longer pedicels than any other variety noted, 20-32 mm. The location of the bracts on the pedicels of different varieties is worthy of note. In "Yemon," for instance, they are close to and often attached to the base of the ovary. On the pedicels of most varieties, the bracts are located about the middle of the pedicel.

The flowers of "Phelps" and "Triumph" are almost urceolate with rounded throat.

The pedicels of all varieties observed are very persistent and may still be found adhering on one and two-year-old and occasionally on three-year-old branches. The sex of a tree may be determined by their presence during the dormant and out-of-flower season.

The economy of the large foliaceous calyx on the pistillate flowers is quite apparent. It serves the same purpose as a leaf in preparing food for the tree, whereas the calyx of the staminate flower is small, of little value in this particular, and is early deciduous.

A careful microscopical examination of many hundreds of stamens of the true type of pistillate flowers has failed to show the presence of pollen in them.

Perfect Flowers.

The perfect flowers of *D. Kaki* are borne singly, in pairs or in three-flowered cymes usually near the base of vigorous shoots which frequently bear staminate flowers in the upper nodes, 13-20 mm. long. The pedicels are short 10-30 mm. long, medium stout, covered with minute hairs. The calyx is 4 parted, intermediate in development between the calyces of the staminate and pistillate flowers. The lobes are more pointed than in the pistillate flowers and often nearly as long as the corolla, smooth and shiny or with only a few scattered hairs. Corolla tubular, urceolate, rounded or quadrangular, resembling the corolla of the staminate flowers, but of greater diameter just above the base, constricted below the 4 recurved lobes, which are deep yellow on the inner surface. Stamens 16 to 24 (generally 16 to 18) in number with well developed pollen bearing anthers and short filaments, the anthers surrounding the stigma and projecting into the throat of the corolla. The ovary is more pointed than in the pistillate form on the same tree, 8-celled; pistil four parted; the stigmatic ends straight, and only slightly divided.

General Notes on the Development of the Flower Parts.

As already stated, the pistil in the staminate flowers, may be rudimentary or it may be entirely lacking, and it has been possible with the staminate, perfect and pistillate flowers to arrange a series ranging from flowers in which there is no sign of an ovary on one side, through to those containing the highest development of the ovary on the other. In such a series it will be noted that other parts of the flower vary in sympathy with the size of the ovary. The calyx is very small where the ovary is lacking, it is slightly larger in specimens having a rudimentary ovary, it is larger still in the perfect flowers and reaches its greatest development in the pistillate form. The corolla is smallest in those flowers having no pistil, its greatest transverse diameter is reached when the pistil increases to its maximum size. If the ovary is lacking, the corolla falls away from the calyx with its base closed, but if the pistil is rudimentary and of some size, the base is open. The opening in the base corresponds to the size of the ovary and varies with it, reaching its largest size in the pistillate flowers. Again in the staminate flowers the number of stamens is 16 to 24, in the perfect flowers usually 16-18 and in the pistillate flowers 8 are found. Broadly speaking, this variation may be stated thus:—when the size of the ovary decreases, the number of stamens increases, reaching the maximum number when the ovary is rudimentary or is lacking entirely.

Grouping Based on Flowering Habit.

Based on the behavior of persimmon trees in the production of flowers the varieties now growing in America may be divided into three groups,—(1) Those on which staminate flowers are never produced,—examples, "Tanenashi," "Tsuru," "Hachiya," "Hyakume," "Tri-

umph'' and ''Costata,''—(2) those on which staminate flowers occur sporadically,—examples,''Taber's No.23,'' ''Okame,''and ''Taber's No.129.'' And (3) those which bear staminate flowers as regularly as the trees bloom—examples, ''Masugata,'' ''Siang'' (S. P. I. No. 21910) and the ''Eagle Lake Tree.'' New ''Sien'' (S. P. I. No. 22368) and S. P. I. No. 27037 are not referred to these latter groups, as they are recent introductions and have come under observation this season (1913) for the first time. It is of course entirely possible that in China and Japan there are varieties of persimmons belonging to the species *D. Kaki* which bear staminate flowers only, and there is a remote though improbable chance that there are trees of which the flowers are all perfect.

The Importance of Pollen Bearing Flowers.

Since the Japan persimmons, *D. Kaki,* were introduced into the United States about forty years ago, there has always been something erratic in their behavior. It has been a common complaint on the part of nearly every one who has attempted their culture, that though the trees bloomed profusely, the young fruits dropped off shortly after the flowering season. At this period, each year, the ground under most trees is often literally covered with the calyces and ovaries of the flowers. At harvest time practically no fruit remains to be gathered. Here and there, for some hitherto unknown reason a tree or group of trees would hold a crop. This phenomenon is now known to be largely due to the unnoticed sporadic production of staminate flowers.

Needless to say, many reasons have been offered for the trees not bearing fruit. By some it was said to be due to improper cultivation, insufficient fertilizer, and lack of moisture. Others held just the opposite. Some even said it was peculiar to certain varieties, and that the growth of the calyces crowded the young ovaries off. All sorts of remedies to meet these different theories were advanced and tried, but in spite of all efforts to

correct the trouble, the Japan persimmons have continued to behave in the same manner.

While it is undoubtedly true that an unhealthy condition of the trees, due to the attacks of borers or other insect pests, or fungi and bacteria, and an insufficient supply of plant food, do effect the holding of a crop of fruit, yet it has been demonstrated that the large cause of the lack of fruitfulness in *D. Kaki* in the Southern and Southeastern states is due to lack of pollenation. It has likewise been amply demonstrated that staminate trees of *D. virginiana* will not serve as pollenizers, no artificial or hand pollenation between the two species having yet been made which resulted in viable seed.

Having in mind these facts, the value of the discovery of dependable varieties of *D. Kaki,* producing pollen bearing flowers, to act as pollenizers, becomes readily apparent. Of the varieties now commonly in cultivation, viz., "Costata," "Hachiya," "Hyakume," "Okame," "Taber's No. 23," "Taber's No. 129," "Tanenashi," "Triumph," "Tsuru," "Yeddoichi," "Yemon" and "Zengi," only one variety, "Tanenashi," a seedless variety, can be depended upon to produce a crop of fruit. This variety does not readily produce seed even when pollenated, hence the production of seedless fruit would not be affected by the proximity of staminate flowers. "Okame" and "Triumph" occasionally bear a fair amount of seedless fruit, but no reliance can be placed on them to do so each time they bloom. The others, and the two last mentioned, as well, are generally worthless unless pollen is provided to fecundate the blossoms. Nectar is secreted abundantly, the flowers are visited freely by bees and other insects, and the blooming periods overlap. Hence there is nothing to interfere with a revision of orchard and garden planting practice to insure the pollenation of *D. Kaki* flowers and the setting of fruit.

EXPLANATION OF THE PLATES.

Plate XXV.—Pistillate Flowers of *D. Kaki*, var. "Yemon." Natural size.

Plate XXVI.—Staminate Flowers of *D. Kaki*, var. "Tabers No. 129." Normal three flowered cymes in lower right-hand corner. Natural size.

Plate XXVII.—Perfect Flowers of *D. Kaki*, var. "Okame." Natural size. Solitary lower flower and upper three flowered cyme.

Plate XXVIII.—Staminate Flowers of *D. Kaki*, var. "Siang," on main central shoot. Two pistillate flowers, unopened, on lateral twig at right. All natural size.

Plate XXIX.—Young fruits of *D. Kaki*, var. "Taber's No. 129." Natural size. Three young fruits from pistillate flowers and one fruit from perfect flower on right hand twig. The latter is attached to same peduncle as the lowest fruit from pistillate flower. Fruit on twig on the right from perfect flower.

Plate XXX.—Fig. 1. Unopened Pistillate flowers of *D. Kaki*, var. "S. P. I. 22,362," showing bracts on the pedicels. Natural size.—Fig. 2. Unopened staminate flowers of *D. Kaki*, var. "Taber's No. 129," showing bracts on pedicels. Natural size.—Figs. 3 and 4. Pistillate and staminate flowers on same pedicel. *D. Kaki*, var. "Eagle Lake tree." Slightly enlarged.—Fig. 5. Two pistillate flowers on same pedicel, *D. Kaki*, var. "Yemon."

Plate XXXI.—Figs. 1-7. Series showing variation in development of calyces. All natural size.—1 and 2. No pistils present.—3 and 4. With small rudimentary pistils.—5. Rudimentary pistil present—quite large.—6. Perfect flower.—7. Pistillate flower.—8-15. Bases of corollas natural size, though No. 9 is an under size specimen.—8. Base of corolla without any sign of ovary.—9. Base of Pistillate flower. "Taber's No. 23."—10 and 11. Bases of perfect flowers, var. "Okame."—12. Corolla of staminate flower without ovary. Var. "Taber's No. 23."—13. Lobes and throat of staminate flower, var. "Taber's No. 23."—14. Corolla of staminate flower without ovary, var. "Taber's No. 129."—15. Lobes and throat of staminate flower, var. "Taber's No. 129."—16 and 17. Three flowered cymes, var. "Okame." Central ones perfect, lateral ones staminate. Natural size.—18. Three flowered cyme "Taber's No. 129." Natural size.—19. Four flowered cyme "Taber's No. 129." Natural size.—20. Two flowered cyme "Taber's No. 129," the central one natural size.—21. Opened corolla of perfect flower showing position and size of stamens. "Okame."—22. Part of corolla removed to show stames and pistil of perfect flower. "Okame." —23. Part of corolla of pistillate flower removed to show pistil and abortive stamens. "Okame."—24. Opened corolla of pistillate flower. "Okame."

Issued December 31, 1913.

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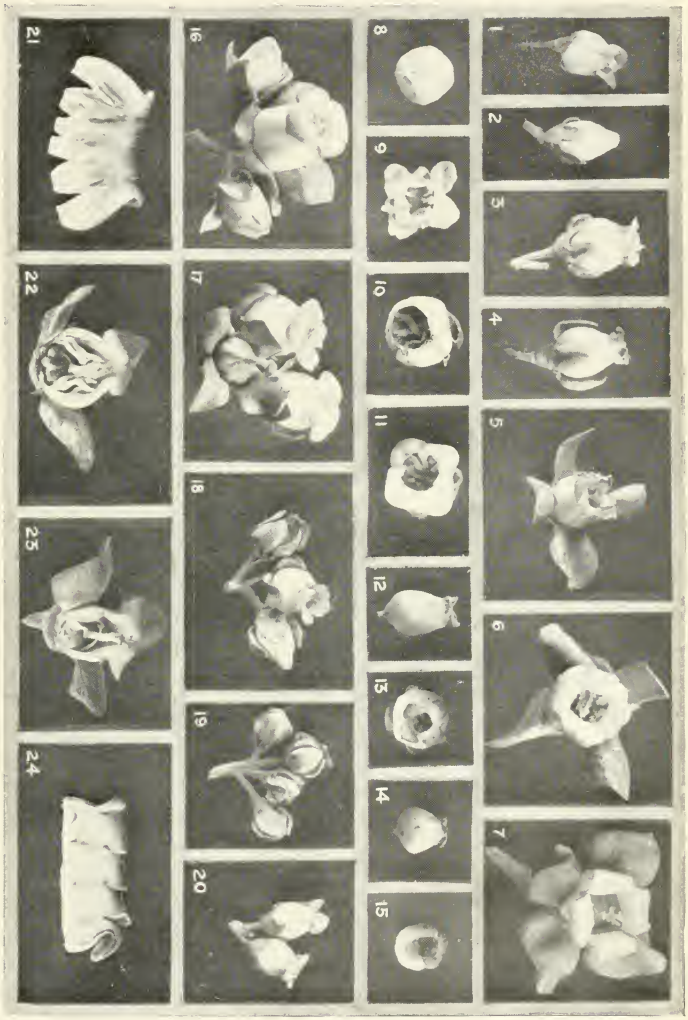

DIOSPYROS KAKI L. F.

Transactions of The Academy of Science of St. Louis.

VOL. XXII. No. 6.

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Issued April 10, 1914.

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